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STUDIES ON THE PRODUCTIVITY OF SOIL ANIMALS IN PASOH FOREST RESERVE, WEST MALAYSIA
I. SEASONAL CHANGE IN THE DENSITY OF SOIL MESOFAUNA : ACARI, COLLEMBOLA AND OTHERS*

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1. Introduction

The ecological studies on soil animals in tropical rain forests have been carried out by many soil zoologists including VAN DER DRIFT (1963), MALDAGUE and HILGER (1963), IMADATÉ and KIRA (1964), OGINO *et al.* (1965), WATANABE *et al.* (1967), BULLOCK (1966 and 1967), GREENSLADE, P. J. M. and P. GREENSLADE (1968), PEREIRA (1969), KITAZAWA (1971), BECK (1971) and LASEBIKAN (1974a, b and 1975). These studies are, however, generally limited to the results of the survey for short term or for the taxa higher than species level, except for the works of PEREIRA (1969), BECK (1971) and LASEBIKAN (1974a). Therefore, there have been remained some difficulties in estimating the secondary productivity of soil animals in tropical rain forest.

In order to estimate the secondary productivity of soil animals in the tropical lowland rain forest, the routine samplings of soil animals were carried out by the authors in Pasoh Forest Reserve, Negeri Sembilan (Sembilan State), West Malaysia, during the period from March 1971 to August 1972. The series of the studies present sea-

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sonal changes in numbers, of vertical distributions and other ecological data of soil animals in a tropical rain forest in West Malaysia.

This study was carried out as a part of the Joint Malaysia/Japan Research Project on Lowland Rain Forest Ecosystems of West Malaysia within the framework of the International Biological Programme.

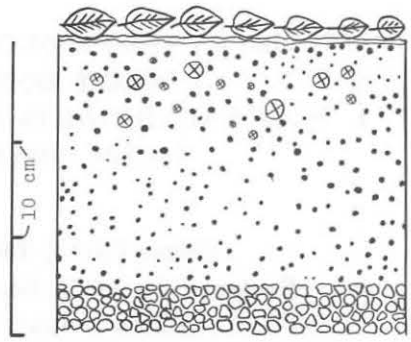


Fig. 1. A modified profile of the soil of Plot 1 in the Pasoh Forest Reserve.

2. Site description and method

2-1. Site description

The study-site was chosen as the IBP Study Area in the Pasoh Forest Reserve. That forest is situated at the northeastern part of Negeri Sembilan, West Malaysia. The IBP Study Area occupies about 650 ha in the middle of the Pasoh Forest Reserve. The forest in the IBP Study Area is a typical lowland rain forest in the tropics, having the flora of *Shorea-Dipterocarpus* group (Fig. 2). There was formed a poor, thin A_0 layer in the forest floor and naked tropical podosol was found somewhere in the forest. A modified profile of the soil in the forest studied was shown in Figure 1. Ten plots were settled for the IBP-project in the area (Fig. 3). Many kinds of the ecological studies by the Japanese IBP Team were carried out mainly in the Plot 1 (100 ×200 m) which includes an undisturbed forest and low undulating hills covered with dominant trees of *Shorea*, *Dipterocarpus*, *Koompassia*, and with other trees as many as ca. 270 species. The general description or the details of the forest were given by SOEPADMO (1973) and YODA (1974).

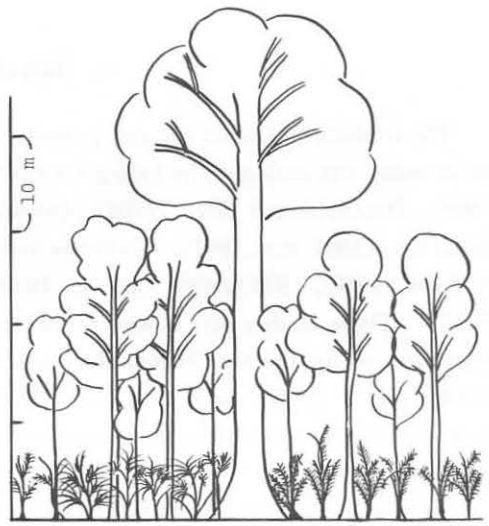


Fig. 2. A modified profile of the forest in Plot 1 (Pasoh Forest Reserve).

2-2. Method

The samplings of soil mesofauna were made on twelve occasions in the subquadrats in the five quadrats (of Nos. 29, 32, 39, 57 and 58) from March 1971 to February 1972 (Fig. 3). Sixteen samplers were used to take soil cores, each 4×5 cm in surface and 5 cm in depth (100 ml), in each subquadrat. Ten of them were applied to the

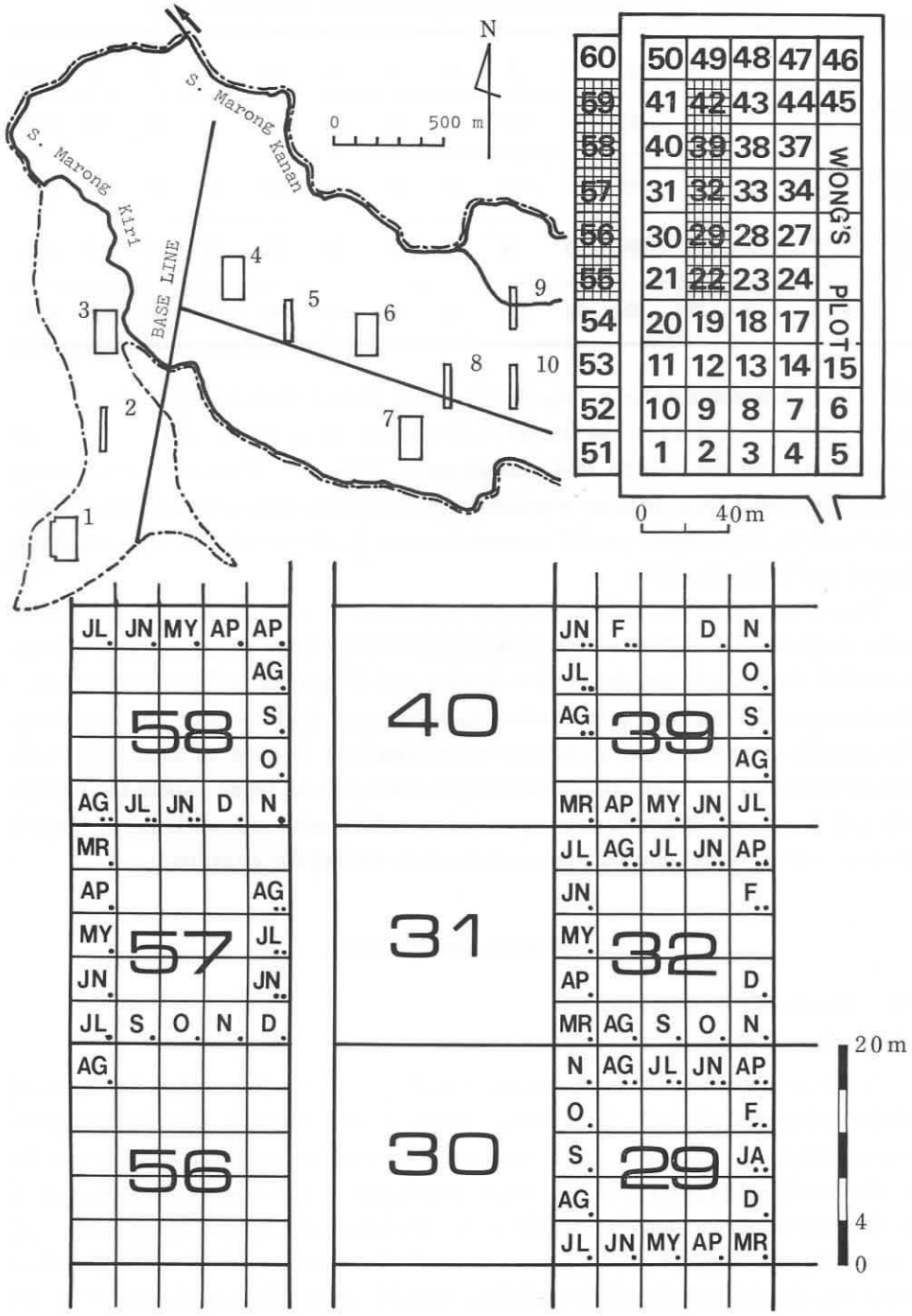


Fig. 3. Map of the Pasoh Study Area and Plot 1 showing the quadrats (each 20 × 20 m) and subquadrats (each 4 × 4 m) prepared for the study on soil animals. One or two dots in subquadrat indicate the year of 1971 and 1972, respectively.

Table 1. Numbers of the sampling core taken during the study.

	1971 M	A	M	J	J	A	S	O	N	D	1972 J	F	Total
First layer 0 — 5 cm	6	50	50	49	49	50	50	50	50	49	29	30	512
Second layer 5 —10 cm	2	20	20	20	20	20	20	20	20	19	12	12	205
Third layer 10 — 15 cm	1	9	10	10	9	10	10	10	10	10	6	6	101
Total	9	79	80	79	78	80	80	80	80	78	47	48	818

first 0 — 5 cm horizon including A_0 (litter) layer, four of them to the next 5 — 10 cm horizon and two of them to the last 10 — 15 cm horizon of the profile. The sample numbers used for the present study are given in Table 1. Only nine samples were collected in March 1971, because a preliminary survey was carried out in that occasion. Unfortunately, an accident caused a great decrease in the number of the samples in January and February 1972.

The extraction of mesofaunal animals contained in each core continued for 48 hours using small Tullgren funnels modified by NIIJIMA (1971). A 40-watt bulb was suspended above each sample unit for heating and drying the core in each funnel. The distance of 7 cm was kept between each core and bulb through the extraction. The animals extracted from each core were separately stocked in small glass vials with 70% alcohol. Then, all animal samples were sent to Japan, where the Collembola and the Acari obtained were mounted on slides with the medium of Hoyer's solution and the other animals were sorted out in alcohol for counting.

3. Results and discussion

3-1. Mesofauna in general

3-1-1. Faunal makeup

A list of the animals obtained is given in Table 2, together with their individual number per square meter in each month. It can be seen that the collection comprises a great variety of arthropods. The majority of the total mesofauna studied were the Acarina made up 50 percent of the whole mesofauna. The dominant group next to the Acarina was Hymenoptera, of which the small-sized ants formed the majority and, in fact, they accounted for 90 percent of total Hymenoptera. The third abundant group was the Collembola which varied the monthly density between 1,000 and 1,500 per m^2. The composition of mesofauna throughout the year is as follows: Acarina (54.1%) ; Hymenoptera (almost Formicidae) (16.6%) ; Collembola (10.4%) ; Diptera (5.4%) ; Psocoptera (1.2%) ; Protura (1.0%) ; Diplura (0.9%) ; Symphyla (0.9%) ; Pseudoscorpiones (0.7%) ; Araneae (0.5%).

Although Collembola hold the third rank next to Acarina and Hymenoptera, that is the significant member to be associated with Acarina. It is wellknown that the ratio of Collembola to Acarina (Co/Ac ratio) is important for reflecting ecological characteristics of a habitat (PACLT, 1956 ; IMATATÉ and KIRA, 1964 ; KIKUZAWA *et al.*, 1965 ; TAMURA *et al.*, 1969). WATANABE and SAICHUAE (1967) noted the higher ratio of the Acarina obtained in Thailand than that in Japan. In the present study, the Co/Ac ratio was always smaller than 1.00. It means the dominancy of Acarina over Collembola throughout the year. The monthly variation in Co/Ac ratio was as follows: April 1971 (0.29) ; May (0.57) ; June (0.07) ; July (0.09) ; August (0.27); September (0.45) ; October (0.86) ; November (0.38) ; December (0.71) ; January 1972 (0.21) ; February (0.19).

It seems that the small collembolan population in the Pasoh Forest is due to poorly developed A_0 layer (litter) in the forest floor. In the place of Collembola, however, Isoptera, Astigmata and other abundant groups seem to play major roles of the decomposition in the Pasoh Forest. In the results of PEREIRA (1969) studied in Bukit Timah Nature Reserve in Singapore, the ratio Co/Ac was 0.27, approximate as the value in the present study, and he also estimated the mesofaunal density from 46,000 to 110,000 per m^2. The authors' estimation in the present study falls within the range of 22,000 to 73,000 per m^2.

The mesofaunal animals with low densities in the tropics where the organic imput is generally high, play a role as a group of the decomposers in harmony with their position, but much of the decomposition depends on the initial breackdown of the litter by macrofauna (mainly by termites) and by bacteria.

3-1-2. Seasonal change

Table 2 shows the seasonal variation in the densities of different taxa in the soil of 0 to 15 cm deep. The densities of most taxa generally took remarkable changes throughout the year in which two or three outstanding maxima and minima occurred. The peaks of maxima appeared during the months from May to August and then it fell steeply until November by forming the second low density in the year. After a considerable decrease of the density another maximum appeared in December to January, and then it decreased. The events mentioned above showed the agreement with the results obtained in temperate regions by TANAKA (1970) and NIIJIMA (1971) who had found that the mesofaunal populations had two maxima and two minima throughout the year. However, they appeared in the different seasons from those in the present study. In tropics, OGINO *et al.* (1965) found that the mesofaunal densities decrease in dry season and increase in wet season, but heavy rainfall tends to decrease the mesofaunal densities. PEREIRA (1969) also mentioned the same consideration as OGINO *et al.*, through his results obtained in Singapore. According to his study, many taxa of soil animals showed two maxima in April to May and October to December 1965 in Singapore. In the Pasoh Forst the peaks and the ravines of the den-

Table 2. Individual number per m² of the mesofauna collected by the Tullgren apparatus from March 1971 to February 1972.

Order \ Month	1971 M	A	M	J	J	A	S	O	N	D	1972 J	F	Total
Mesostigmata	600	2,200	1,390	1,433	1,371	1,925	510	570	1,185	1,858	2,982	1,067	17,091
Prostigmata	336	666	875	1,722	1,881	1,665	735	885	1,565	666	1,881	1,190	14,067
Acaridae	1,667	5,451	4,155	54,675	47,573	8,895	2,015	980	4,155	7,950	11,946	9,848	159,310
Oribatei	2,700	2,715	1,470	1,505	1,930	2,355	1,035	1,555	1,700	1,315	2,083	1,318	21,681
Heterostigmata		120	50	292	1,795	230	630	125	420	151	125	258	4,196
All Acarina	5,303	11,152	7,940	59,627	54,550	15,070	4,925	4,115	9,025	11,940	19,017	13,681	216,345
Collembola	3,100	3,550	4,715	4,091	3,446	4,600	2,585	2,813	3,835	940	2,180	759	36,614
Diplura	500	210	375	286	227	375	190	260	80	361	646	467	3,977
Protura	450	205	700	480	647	580	270	100	345	109	292	67	4,245
Thysanura				41					25	11			77
Blattoidea		20	10			10			10		42		92
Isoptera	800	550	955	46	3,117	40		1,285	3,000	180	2,498	582	13,053
Orthoptera				11									11
Ssocoptera		430	50	479	456	740	340	605	985	209	293	500	5,087
Thysanoptera		185		72	56		45	20	50	27	42		497
Hemiptera		1,070	435	138	432	745	460	2,630	275	1,047	481	318	8,031
Lepidoptera		265	10	47		60	50	45	10	124	105		716
Diptera		8,270	320	279	813	835	1,560	1,760	1,400	2,635	3,663	1,040	22,575
Coleoptera	550	880	410	577	300	550	230	425	405	352	731	459	5,869
Hymenoptera	2,900	9,230	1,190	3,307	1,646	6,635	12,555	10,450	3,430	10,137	5,992	2,495	69,967
Diplopoda		10	30	31	21	20	20	20	20	50		17	239
Chilopoda	400	65	75	62	107	85	50	35	470	74	104	17	1,544
Symphyla	350	165	265	458	414	360	95	115	190	129	875	243	3,659
Pauropoda		165	135	343	274	465	195	205	295	101	334	251	2,763
Scorpiones					11								11
Pseudoscorpiones	300	225	205	225	276	440	145	240	220	72	333	150	2,831
Schizomida			20	36	91	140		105	20	61	84	34	591
Opiliones				61		10					21		92
Araneae	100	120	180	263	204	255	95	60	105	205	292	208	2,087
Isopoda			25	62	11			170	90	102	125	17	602
Oligochaeta	100	20	20		11	75					84	17	327
Neuroptera		75											75
Polyxenoidea		10			11	20	20	10					71
Nematoda		200	70		41								311
Copepoda			10	11	25								46
Total	14,853	37,072	18,145	71,033	67,187	32,110	23,830	25,468	24,285	28,866	38,234	21,322	402,405

sity appeared one or two months later than those in Singapore.

3-1-3. Vertical distribution

The vertical distribution of the mesofauna throughout the twelve occasions was given in Fig. 4. It was shown that 61.0% of the total mesofauna aggregated in the first soil horizon (0—5 cm), 20.0% occurred in the second horizon (5—10 cm) and 19.0% in the third horizon (10—15 cm).

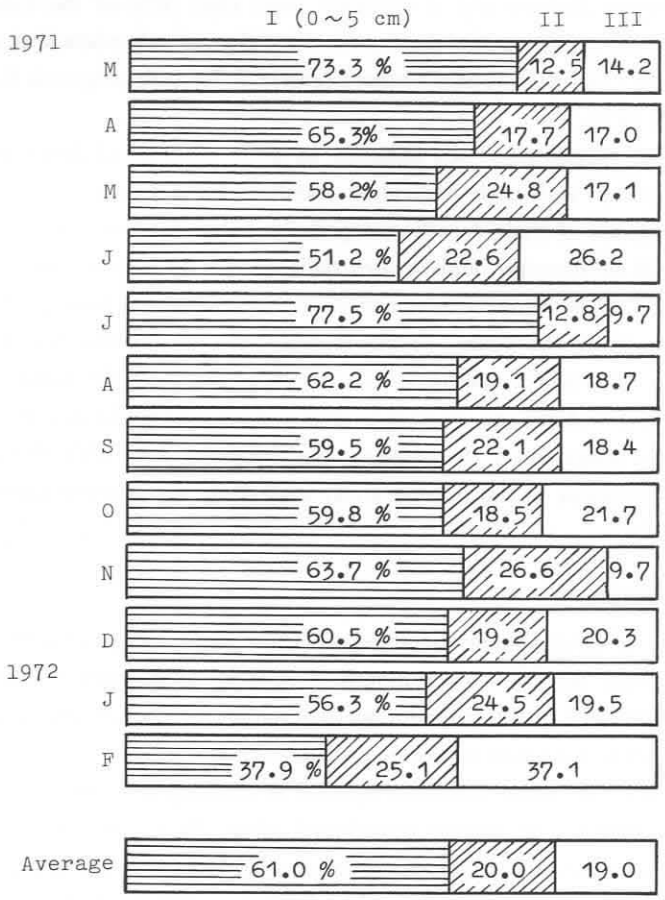


Fig. 4. Vertical distribution in percentage of total animals collected by Tullgren funnels from March 1971 to February 1972.

Seasonal variations in depth-distribution have been observed by several researchers. In Hokkaido, northern Japan, TAMURA *et al.* (1969) demonstrated that in warm and hot seasons Collembola aggregated in the upper layer, and when cold season come, they tended to penetrate into deeper layers in parallel with fall of temperature. BELFIELD (1956) and OGINO *et al.* (1965) mentioned that the mesofauna responded to dryness by moving downwards into the lower horizon of the soil. In the present study, some taxa of the mesofauna did reveal their seasonal variations in the depth-

distribution. In the months preceded by very low or excessive rainfall, the mesofauna, especially Astigmata, showed increases in the horizon below 5 cm. The relative increase of the mesofauna in the third horizon (10 — 15 cm in depth) in January 1972 was probably caused by the Astigmata penetrated into deeper horizons.

3-2. Acarina

The Acarina was the most dominant group among the whole animals of mesofauna in the Pasoh Forest Reserve and it occupied more than 50% of the total mesofaunal density. The proportion in the density of the different suborders was as follows: Astigmata 70.2% ; Oribatei 13.9% ; Mesostigmata 7.7% ; Prostigmata 6.1% ; Heterostigmata 2.1% (Fig. 5).

The seasonal variations of the densities in each suborder of Acarina were shown in Figure 6 together with their individual numbers in each occasion. All the taxa indicated three peaks of their densities, especially Astigmata indicated very sharp ones both in June and in January, and besides their minimal densities appeared in September or October. Gradual increment and decrement were observed in the other three suborders throughout the year. Total number of the Acarina had two excessive maxima in June 1971 and in January through the period and the former was twice as large as the latter. Although PEREIRA (1969) estimated a density of total Acarina only, the trends obtained in the present study agreed well with PEREIRA's result, except that the maxima in the present study appeared two or three months later than those in his study.

3-2-1. Prostigmata

The species of Prostigmata extracted were given in Table 3 together with their individual numbers per m^2 in each month. A total of 42 species belonging to 31 genera and 18 families of Prostigmata were obtained in the present study and a majority of the species were new to science (SHIBA, in press).

It is clear that the most abundant species of Prostigmata was *Pronematus davisi* BAKER. In average, this species constituted about 36.5% of the total number of Prostigmata and it was no exaggeration to say that the total number of Prostigmata was corresponded with fluctuation of this species. Other abundant species were *Eupodes pusillus* SHIBA (8.8%), *Nanorchestes* sp. (8.5%), *Phagidia strandtmanni* SHIBA (8.2%), *Eupodes pasohensis* SHIBA (4.8%) and *Spinibdella bifurcata* ATYEO (5.5%).

The dominant species occupying more than 5% of total individual number in each month are as follows:

March (1971) : ① *Pronematus davisi* (25.0%)—② *Eupodes pasohensis* (25.0%)

April : ① *P. davisi* (25.7%) — ② *E. pasohensis* (13.5%) — ③ *Eupodes pusillus* (10.5%) — ④ *Nanorchestes* sp. (9.0%)

May : ① *E. pusillus* (33.1%) — ② *Nanorchestes* sp. (25.1%) — ③ *E. pasohensis*

Table 3. Individual number per m² of the species of Prostigmata from March 1971 to February 1972.

Species \ Month	1971 M	A	M	J	J	A	S	O	N	D	1972 J	F	Total
Eupodes berensis						35							35
Eupodes pasohensis	84	90	95	51	87	105	20	60		27		50	669
Eupodes pusillus		70	290	208	244	205	10	60	65	11	63	17	1,243
Linopodes cameronensis						20			50				70
Rhagidia pseudocrenata				11		25							36
Rhagidia neoshibai		10		21	25	10	40	30		11	21		168
Rhagidia strandtmanni		30	70	71	127	225	105	85	210	48	104	84	1,159
Bdella tropica				11	11								22
Spinibdella bifurcata		10		50	112	95		250	80			185	782
Cunaxa taurus		25	20				30		20		21		116
Cunaxa setirostris	84	75			11	20						84	274
Cunaxoides pseudominutus			20			50		10		48	84		212
Cunaxoides parapatzcuarensis											21		21
Coleoscirus ogawai		20	20	25	11	45	150		10	50	147		478
Tydeus sp.		35				25			10		84	42	196
Pronematus davisi	84	171	55	818	919	445	230	120	875	305	727	384	5,135
Ledermuelleria mixta					11						21		32
Zetzellia ikushimai				11			10						21
Raphignathus satoi									10				10
Cheletogenes onoi					11	10	10				42		73
Cheyletia tropica			10		31		10						51
Sphaerolichus barbarus		10		36	36	60			50	38	42		272
Hybalicus flabelliger				21									21
Lodalychus peraltus		10		25	11	100			30		21		197
Nanorchestes sp.		60	220	182	102	50	50	100	125	31	104	167	1,191
Alicorhagia bullocki			25	25		20			10	11			91
Alicorhagia sp.				22	11		20						53
Bimichaelia arbusculosa			30	41		40	20	30			21	17	199
Anystis baccarum						10							10
Ereynetes (E.) fusatoi				11	11		10	70			209		311
Neoabrolophus hirsutus								10					10
Leptus yoshimii		10						10					20
Leptus chibai					11								11
Clipeosoma furtadoi				50								84	134
Dromeotrombidium copiosum	84										42		126
Dromeotrombidium yosiii				21	11								32
Microtrombidium jabanicum			10		42	20	10	10			21	34	147
Echinothrombium hystricinum				11									11
Echinothrombium tritypum		10	10		21	30					21		92
Holcotrombium dentipile							10	10			21		41
Ettmuellia punctatum		10								11			21
Trombiculidae		10						20	10	11	42		93
Water mite (larva)		10			25	10		10	10	64		42	171
Total	336	666	875	1,722	1,881	1,665	735	885	1,565	666	1,881	1,190	14,057

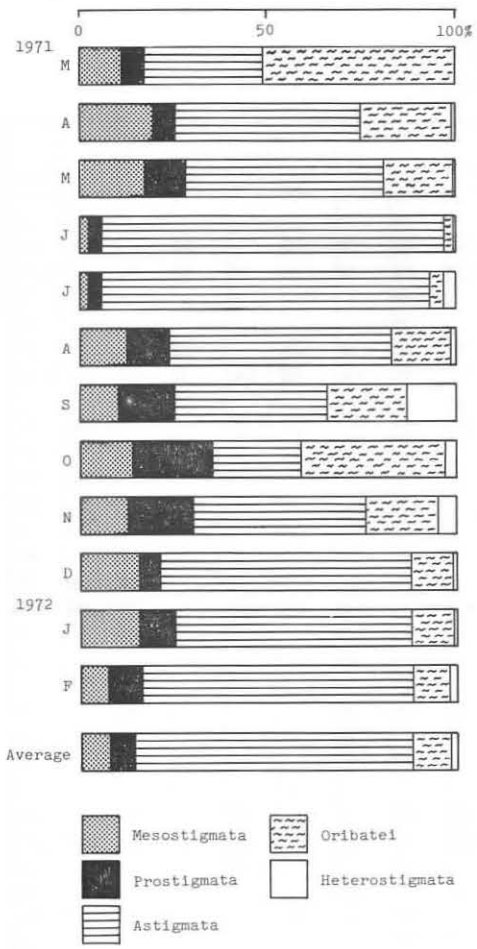


Fig. 5. Seasonal change in the percentage of different groups of mites from March 1971 to February 1972.

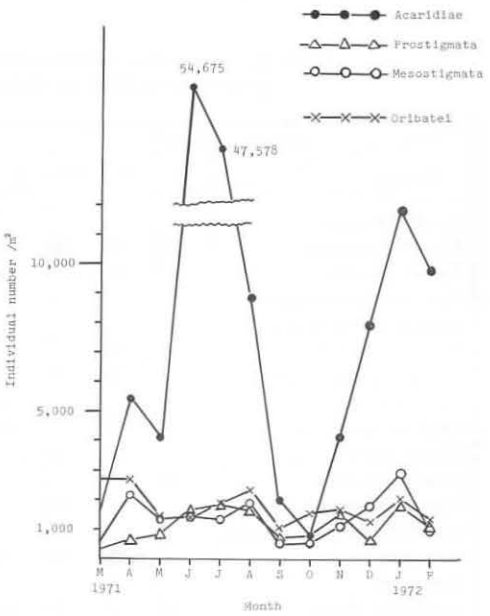


Fig. 6. Seasonal change in the individual numbers of different suborders of Acarina from March 1971 to February 1972.

Table 4. Individual number per m² of the families of Prostigmata from March 1971 to February 1972.

Family \ Month	1971 M	A	M	J	J	A	S	O	N	D	1972 J	F	Total
Eupodidae	84	160	385	259	331	365	30	120	115	38	63	67	2,017
Rhagidiidae		40	70	103	152	260	145	115	210	59	125	84	1,363
Bdellidae		10		61	123	95		250	80			185	804
Cunaxidae	84	120	60	25	22	115	180	10	30	98	273	84	1,101
Tydeidae	84	206	55	818	919	470	230	120	885	305	813	426	5,331
Endeostigmata		80	275	352	160	270	90	130	215	80	188	184	2,024
Erythraeoidea		10		50	11			20				84	175
Trombidoidea	84	30	20	32	74	50	20	40	10	22	147	34	563
Others		10	10	22	89	30	40	80	20	64	272	42	679
Total	336	666	875	1,722	1,881	1,655	735	885	1,565	666	1,881	1,190	14,057

(10.9%) — ④ *Rhagidia strandtmanni* (8.0%) — ⑤ *P. davisi* (6.3%)

June : ① *P. davisi* (47.5%) — ② *E. pusillus* (12.1%) — ③ *Nanorchestes* sp. (10.6%) — ④ *R. strandtmanni* (4.1%)

July : ① *P. davisi* (48.9%) — ② *E. pusillus* (13.0%) — ③ *R. strandtmanni* (6.8%) — ④ *Spinibdella bifurcata* (6.0%) — ⑤ *Nanorchestes* sp. (5.4%) — ⑥ *E. pasohensis* (4.6%)

Aug. : ① *P. davisi* (26.9)— ② *R. strandtmanni* (13.6%) — ③ *E. pusillus* (12.4 %) — ④ *E. pasohensis* (6.3%)

Sept. : ① *P. davisi* (31.3%) — ② *R. strandtmanni* (14.3%) — ③ *Nanorchestes* sp. (6.8%)

Oct. : ① *S. bifurcata* (28.3%) —② *P. davisi* (13.6%) — ③ *Nanorchestes* sp.(11.3 %) — ④ *R. strandtmanni* (9.6%) — ⑤ *E. pusillus* (6.8%) = *E. pasohensis* (6.8%)

Nov. : ① *P. davisi* (55.9%) — ② *R. strandtmanni* (13.4%) — ③ *Nanorchestes* sp. (8.0%) — ④ *S. bifurcata* (5.1%) — ⑤ *E. pusillus* (4.2%)

Dec. : ① *P. davisi* (45.8%) — ② *R. strandtmanni* (7.2%) — ③ *Nanorchestes* sp. (4.7%) — ④ *E. pasohensis* (4.1%)

Jan. (1972) : ① *P. davisi* (38.8%) — ② *Nanorchestes* sp. (5.5%) =*R. strandtmanni* (5.5%)

Feb. : ① *P. davisi* (32.3%) — ② *S. bifurcata* (15.6%) — ③ *Nanorchestes* sp. (14.0%) — ④ *R. strandtmanni* (7.1%) — ⑤ *E. pasohensis* (4.2%)

3-2-1-1. Seasonal change

Fig. 7 shows the seasonal change of the total number of Prostigmata indicated 95% confidence intervals and the number of species sampled in each month. It is remarkable that the Prostigmata community in the forest has three peaks of the density in January, June～August and November. The maximum of density in July amounts to 2.8 times the minimum of it in December. The three peaks of individual number are nealy identical (ca. 1,700/m^2).

In Prostigmata, the species number was associated with the individual number in the Pasoh Forest. When the individual number reached its peak, the species number also reached its maximum of about twenty species.

Seasonal changes in the percentage and the number of each dominat species of Prostigmata are shown in Figs. 8 and 9. *Pronematus davisi* had three peaks of population throughout the year, in June-July, November and January, respectively. *Eupodes pusillus*, *E. pasohensis* and *Nanorchestes* sp. had nearly same fluctuations as *P. davisi*, though the phenological pattern is rather different among them. It seems that the peak of the typical carnivorous species as the genus *Rhagidia* falls behind the other species (Fig. 9).

3-2-1-2. Vertical distribution

It is wellknown that the Acarina community is rich in upper soil layer, gradually

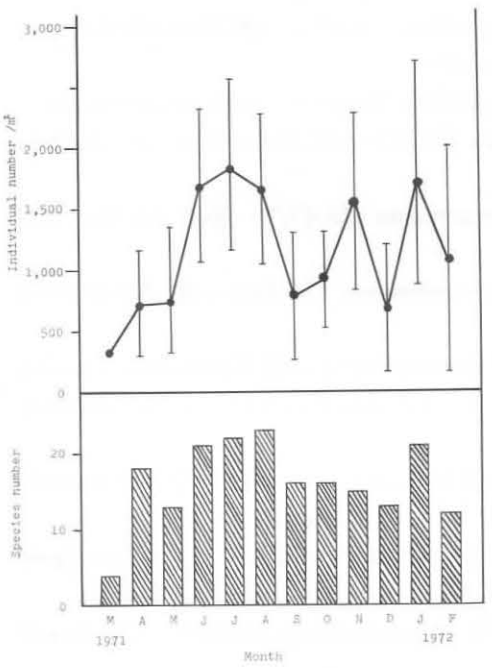


Fig. 7. Seasonal change in total individual numbers per m² and species numbers of Prostigmata for each month. The length of the vertical bar indicates the standard deviation of the mean.

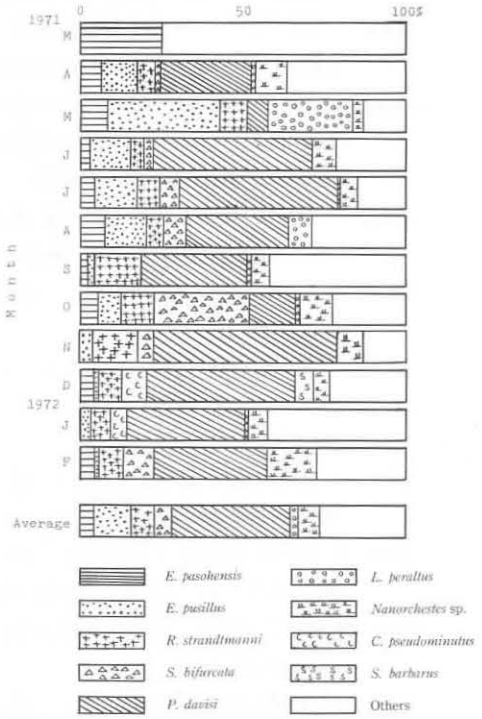


Fig. 8. Seasonal change in percentage of the dominant species of Prostigmata.

Table 5. Individual number per m² of Heterostigmata and Acaridae from March 1971 to February 1972.

	Month / Genus or Family	1971 M	A	M	J	J	A	S	O	N	D	1972 J	F	Total
Heterostigmata	Scutacaridae		40	30	31	62	10	80	10	50	113	125		551
	Tarsonemidae		80	20	225	1,733	220	550	70	370	38	258	258	3,564
	Pyemotidae				36				45					81
	Total		120	50	292	1,795	230	630	125	420	151	125	258	4,196
Acaridiae	*Tyroglyphus* spp.	1,667	346	560	203	168		965	460	390	537	21	292	5,609
	Rhizoglyphus spp.		1,519	2,690	54,172	46,736	8,845	1,050	510	3,715	7,402	11,925	9,539	148,103
	Glycyphagus spp.		3,586	905		613	50		10	50	11		17	5,242
	Anoetidae				300	56								356
	Total	1,667	5,451	4,155	54,675	47,573	8,895	2,015	980	4,155	7,950	11,946	9,848	159,310

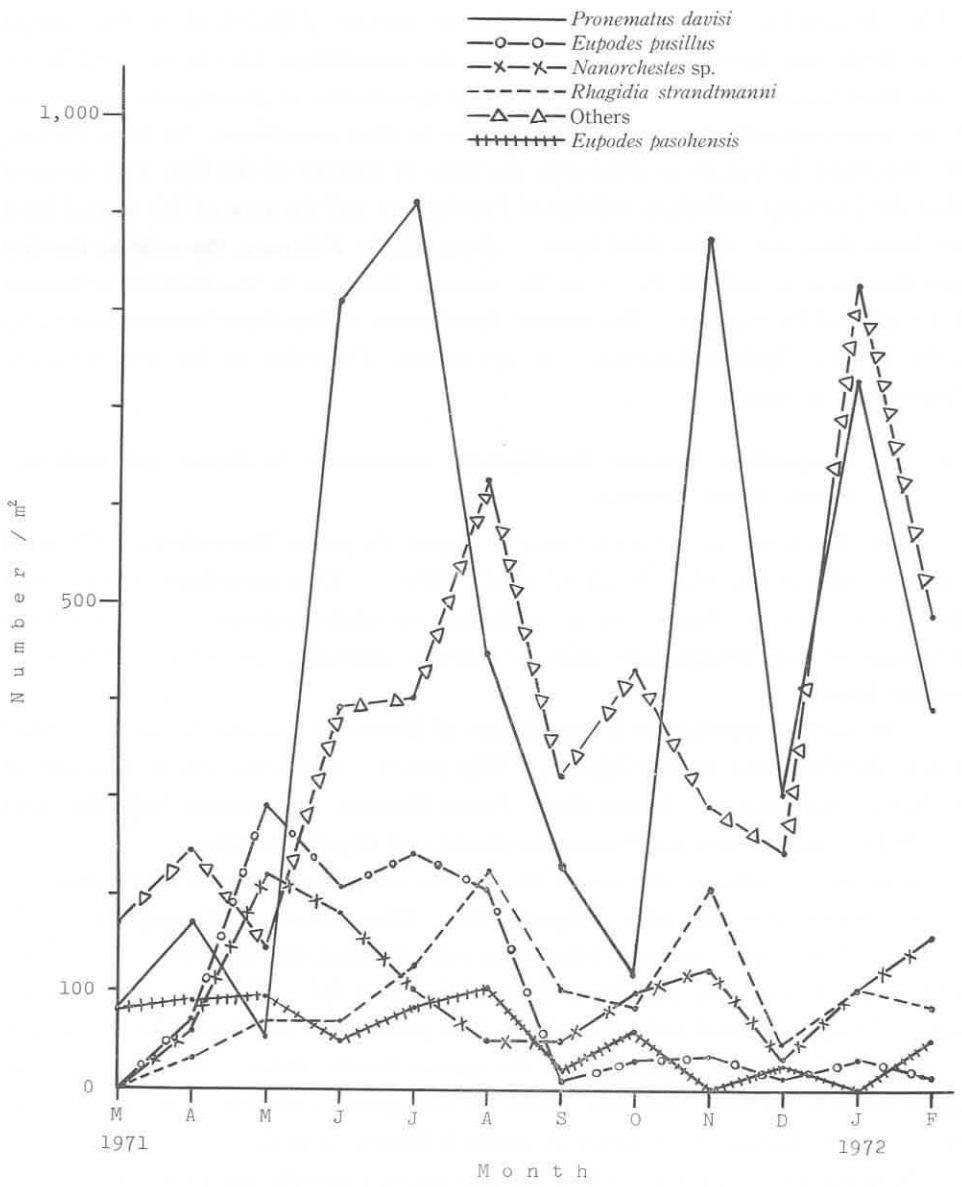


Fig. 9. Seasonal change in number of dominant species of Prostigmata in the soil layer 0—15 cm deep.

decreasing in individual number in deep layer, to be parallel to the diminution of other mesofauna. The vertical distribution of Prostigmata and its monthly change is shown in Figs. 10 and 11. As shown in Fig. 10, an average of 55.7% of the Prostigmata occurs in the top layer (0—5 cm), 21.5% in the second layer (5—10 cm) and 22.8% in the third layer (10—15 cm). The vertical distribution of Prostigmata heavily fluctuates compared with the general trend shown by total mesofauna. In June, September, December as well as in February, the ratio in number of the first layer dropped below 50% of total individual number of Prostigmata and the ratio of the second layer was lower than that of the third layer. Especially in February, the ratio in the first layer decreased to only 31.7% ; on the contray, the ratio in the third layer became 53.1% of total Prostigmata. The ratio of Prostigmata at deep layer increases gradually in dry season (April to August). In wet season (December to January) a similar phenomenon is traced.

3-2-1-3. Comparison between Prostigmata community in Japan and that in Pasoh Forest Reserve

In the forest soils of temperate zone as Japan, the genus *Nanorchestes* is the most abundant mite in Prostigmata (AOKI *et al.*, 1970). They sometimes occupy more than 50% of total Prostigmata in the coniferous or subalpine forests. However, their percentage of total Prostigmata tends to decrease gradually toward low latitudes or lowland forests.

In the soils of laurilignosa the population of *Nanorchestes* seems to become smaller than in deciduilignosa or aciculignosa. This pattern of decrease can be also seen in the case of Collembola. In the Pasoh Forest Reserve, *Nanorchestes* holds the third rank in Prostigmata next to *Pronematus davisi* and *Eupodes pusillus*.

In Japan, the mites of the genus *Pronematus* are generally found in the dust of a granary, being associated with Astigmata (e.g. *Glycyphagus* or *Tyrogylphus*). In the Pasoh Forest, the astigmatid mites were very abundant and the peaks of their density occurred in the same months as those of *P. davisi* did. These two taxa of mites may be closely associated with each other. The presence of three remarkable peaks of the density of *P. davisi* suggests that the species breeds thrice a year. It may be significant that the most abundant period of this species coincides with the peaks of the density of Astigmata, on which *P. davisi* is known to feed.

From the data obtained in the temperate zones, especially on the basis of the results in Shiga Heights (AOKI *et al.*, 1968, 1970), it can be seen that there are some differences in the density of Prostigmata occurred in the tropics and in the temperate zones. The density of Prostigmata was estimated within the range of 4,000—20,000 per m^2 in Shiga Heights, while it estimated as much as 600—2,000 per m^2 in the Pasoh Forest. On the other hand, twenty-three species of Prostigmata was found in Shiga Heights, but the Prostigmata in the Pasoh Forest consisted of fourty species. The prostigmatid community in the tropical rain forest such as the Pasoh Forest should be

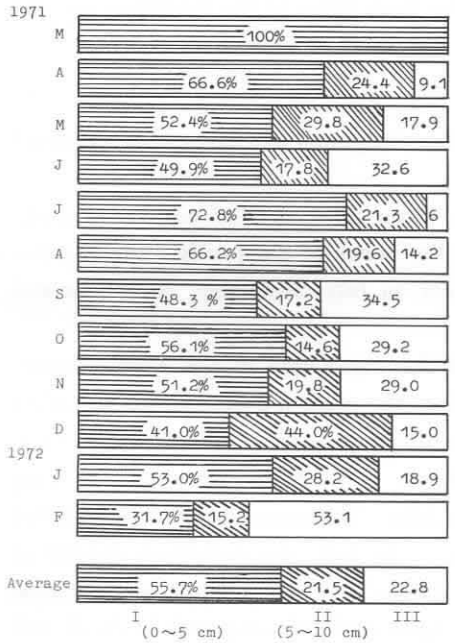


Fig. 10. Vertical distribution in percentage of the prostigmatid mites collected by the Tullgren apparatus from March 1971 to February 1972.

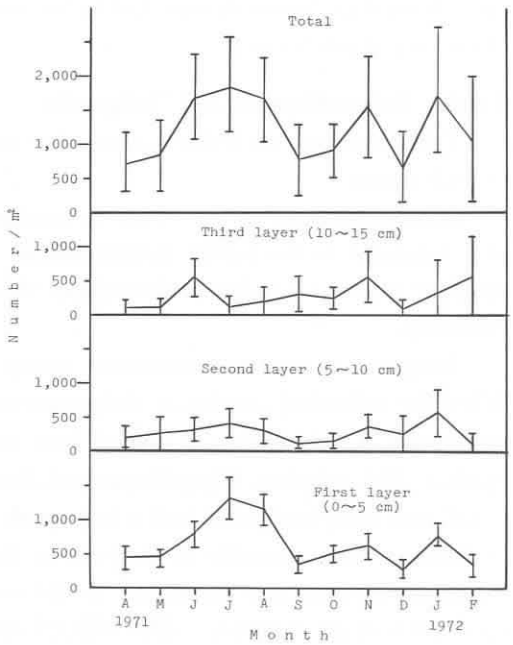


Fig. 11. Seasonal change in total number and 95% confidence intervals of Prostigmata for each month.

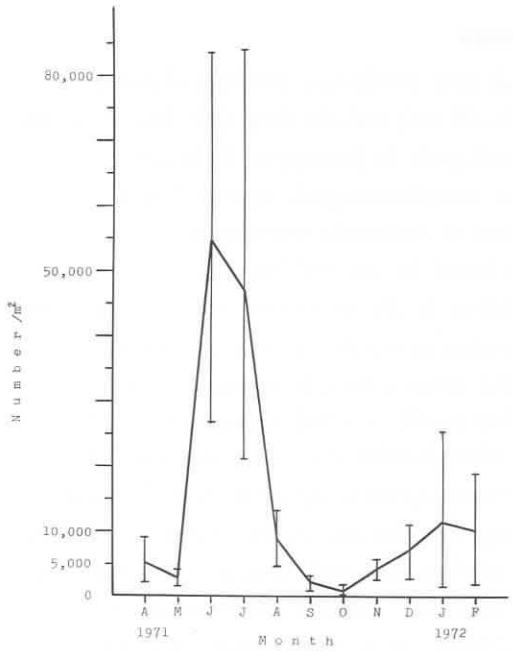


Fig. 12. Seasonal change in total number and 95% confidence intervals of Acaridiidae in the soil layer 0—15 cm.

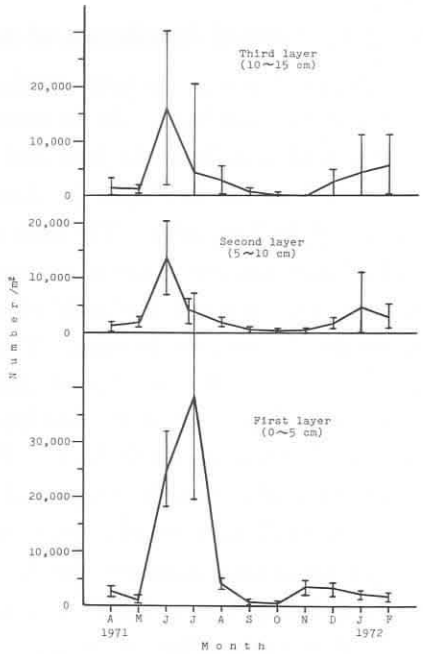


Fig. 13. Seasonal change in total number of each soil layer and 95% confidence intervals of Acaridiae.

characterized by lower density and richer species than those in the temperate or subalpine coniferous forests.

3-2-2. Heterostigmata and Astigmata

Table 5 shows the individual number of Heterostigmata and Astigmata extracted in each month.

Heterostigmata was very poor in number, about 50—1,800/m^2 and the majority of it belonged to the family Tarsonemidae. The mites of the family Tarsonemidae had four peaks of population throughout the year, in July, September, November and February.

Astigmata is the most important group of the mesofauna in the Pasoh Forest. When the individual number of Astigmata reached the peak, it overwhelmed the other mesofauna. Astigmata was divided here into four genera or families, namely *Tyroglyphus*, *Rhizoglyphus*, *Glycyphagus* and Anoetidae. The *Rhizoglyphus* species were found very abundantly and had a large peak in July. The second peak of it occurred in January with a quarter of the peak in July. In July, the maximum density of *Rhizoglyphus* spp. was 54,000/m^2 in the soil layer of 0—15 cm depth and occupied about 90% of all Acarina. The *Glycyphagus* mites had only one peak in April, and in the remaining months they were very few in number.

Figure 11 shows the total numbers and 95% confidence intervals of Astigmata in each month. The total numbers of Astigmata had two notable peaks in July and January and a trough in October.

3-2-2-1. Vertical distribution of Astigmata

Figure 12 shows the total number and 95% confidence intervals of Astigmata in each depth of soil layer. At the second (5—10 cm) and the third (10—15 cm) layers, a large peak was found in June and a small peak in January or February. On the other hand, in the first layer (0—5 cm), a conspicuous peak appeared in July and a small peak in November. The total numbers of Astigmata was maximum in June due to the large number of larvae or nymphs found in the soil layer under 5 cm depth. In July, they reached the peak of population in the first layer, while in the other layers they become to decrease. The minimum in number was seen in October in all the soil layer. The number of astigmatid mites gradually increased after October under 5 cm depth, but in the first layer, they rapidly reached a small peak in November and decrease gradually later. From these results, it is suggested that the astigmatid mites were born in deeper soil layer and moved to upper layer as they grew.

It is wellknown by laboratory breeding experimentation on Acaridiae that the population density increases rapidly and reaches the peak during only one or two weeks and then they suddenly decrease in number. In the present study, it must be noted that the numbers of younger individuals (larva and nymph) increase in June and January. The percentage in number of each growth stage to total Astigmata in some months were as follows: June—larva 80.2%, nymph 10.5%, adult 9.3%. July

Table 6. Individual number per m² of the species of Mesostigmata from March 1971 to February 1972.

Month / Species	1971 IV	V	VI	VII	VIII	IX	X	XI	XII	1972 I	II	Total
Macrocheles sp.				11		10						21
Parholaspulus sp. 1	190	20	51	21	165	30	20	10	191	728	63	1,489
Parholaspulus sp. 2	20	165	31									216
Gamasholaspis sp.		30										30
Parholaspis sp.	10	50							31			91
Neparholaspis sp.	10		21	21	10			20	21	42	21	166
Rhodacarus sp.	30		41	21	210	20	60	205	72	209	84	952
Gamasiphis sp.	20		72	215	135	30	50	50	68	146		786
Gamasellus sp.		10	21						11			42
Hydrogamasus sp.	10	20	81	11	30	20		70	72	21	21	356
Hydrogamasellus sp.	30	90	51	61	30	20	30	60	68	84		524
Heydeniella sp.			51	21				20				92
Sessiluncus sp.				11								11
Geogamasus sp.				11								11
Ologamasus sp.		50										50
Ameroseius sp.	120					25		10				155
Digamasellus sp.	50	130	46				50					276
Asca aphidioides	10		11	31	140		20	10	11			233
Asca sp. 2												
Proctolaelaps sp.	20	10										30
Iphidozercon sp.	541											541
Blattisocius sp.	30			11	60	130	20	30	208	21	230	740
Lasioseius sp. 1	170			21		10			50			251
Lasioseius sp. 2	40											40
Cheiroseius sp.		20										20
Zerconopsis sp.		20										20
Phytoseius sp.	298				10				11		104	423
Laelaps sp.	80	10		11			10		31	42		184
Hypoaspis sp.	20	300	189	239	515	35	20	290	341	250	210	2,409
Pergamasus sp.	10		11									21
Podocinum sp.	10	10	31	21	10							82
Eviphis sp.		10			50			50	38	63		211
Pachylaelaps sp.		35										35
Liroaspis sp.	10											10
Uropoda sp. 1	155	230	398	380	305	50	100	135	245	625	167	2,790
Uropoda sp. 2		30	71			30			11			142
Trachytes sp.	160	30	184	72	155	40	120	50	133	104	63	1,111
Larvae	156	120	72	269	100	60	70	175	245	647	104	2,018
Total	2,200	1,390	1,433	1,459	1,925	510	570	1,185	1,858	2,982	1,067	16,579

— larva 50.8% nymph 34.2%, adult 15.0%. In the other months, the percentage of adult stage to total Astigmata was about 50%.

Although the explosive appearance of Astigmata in June and July 1971 was found in all subquadrats of Plot 1, it could not be found in the samples collected sporadically in 1972 after the routine work. The numbers of Astigmata picked up from the sporadical samples on some months in 1972 were as follows: April 1,488/m^2; July 975/m^2; September 1,575/m^2. These samples were collected by the same methods used in the course of the routine sampling. The population densities of the Astigmata obtained in July and September 1972 were estimated about 1/10～1/4 of those in 1971. 71.8% of total Astigmata obtained in July 1972 were larval stage and in September 1972, 6.4% of them were larval stage.

It can be concluded that the Acarina is the most abundant taxon of mesofauna in a tropical rain forest owing to an extremely large number of astigmatid mites; the other taxa of mesofauna are not so abundant and their individual numbers keep almost fixed level throughout the year. From the results of PEREIRA (1969) in Singapore, it can be seen that the Acarina had two distinct peaks a year. It may be thought that these two peaks are consistent with great occurrence of Astigmata, although he did not make the taxonomical explanations on it.

In Shiga Heights, central Japan, Astigmata was abundant in spring and late autumn; the maximum number in December was about 4,500 per m^2 (AOKI *et al.*, 1970).

3-2-3. Mesostigmata

A total of 37 species belonging to 33 genera of 15 families of mesostigmatid mites were obtained by quantitative sampling in investigated area from 1971 to 1972. As to the individual number, mesostigmatid mites hold the third rank next to Acaridae and Oribatei, occupying 2.3—18.0% (7.5% on an average) of total Acarina. Compared with the result obtained in Mt. Shiga (central Japan, VII—IX 1969), the individual number per square meter in Malaysia, 510—2,980/m^2, is about 1/6 as large as that of Mt. Shiga, 3,730—18,370/m^2. It is very interesting to find that in Malaysia there are a lot of varieties of mesostigmatid mite fauna but a very small individual number. The monthly fluctuation of the individual number (Table 6, Figure 14) shows that the individual number is the lowest in September (510 individs./m^2) and increases rapidly in October to January, in which it reaches the highest point about five times as large as that in September. Smaller peaks are also found in April (2,200/m^2) and in August (1,925/m^2), while smaller troughs are found in May (1,390/m^2) and in February (1,067/m^2). In the subalpine coniferous forests and in the temperate laurel forests in Japan, the highest peak of the individual number appears in October and the individual number decreases from December to March. It seems that the difference between these two is caused by environmental factors, such as temperature, moisture, season of leaf fall, quantity of Collembola and Nematoda as food. The change in

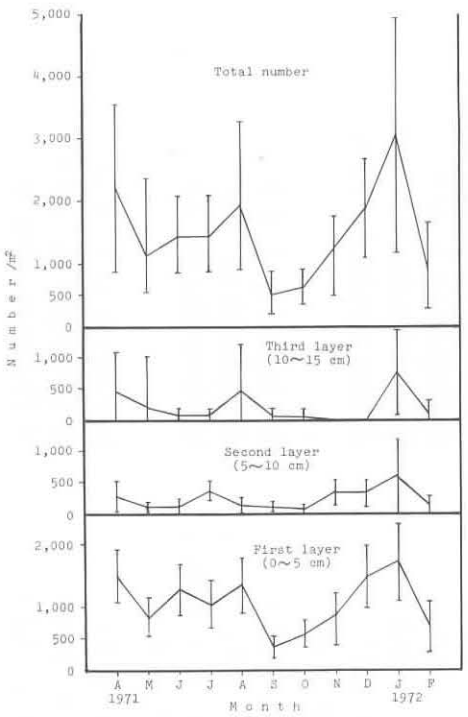


Fig. 14. Seasonal change in total number and 95% confidence intervals of Mesostigmata for each month.

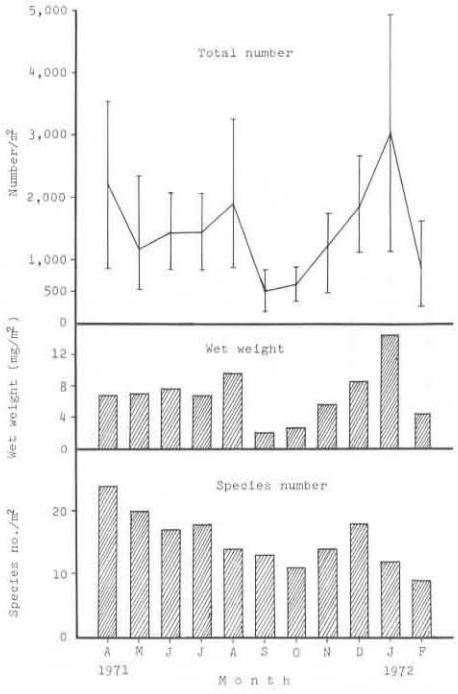
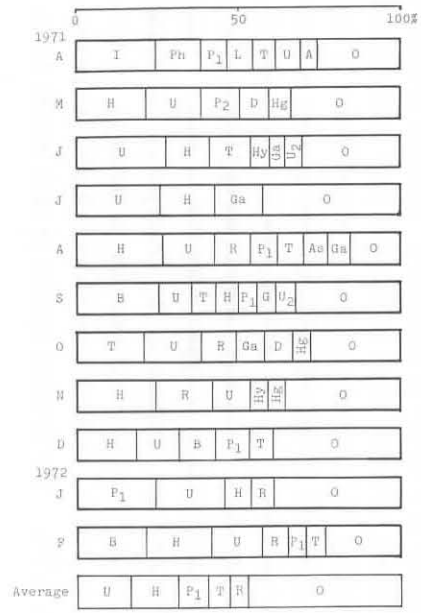


Fig. 15. Seasonal change in total number per m² and wet weight per m² and species number of Mesostigmata for each month.



A : *Ameroseius* sp.
As : *Asca aphidioides*
B : *Blattisocius* sp.
D : *Digamasellus* sp.
G : *Gamasellus* sp.
Ga : *Gamasiphis* sp.
H : *Hypoaspis* sp.
Hg : *Hydrogamasellus* sp.
Hy : *Hydrogamasus* sp
I : *Iphidozercon* sp.
L : *Lasioseius* sp.
P_1 : *Parholaspulus* sp. 1
P_2 : *Parholaspulus* sp. 2
Ph : *Phytoseius* sp.
R : *Rhodacarus* sp.
T : *Trachytes* sp.
U : *Uropoda* sp. 1
U_2 : *Uropoda* sp. 2
O : Others

Fig. 16. Seasonal change in percentage of the dominant species of Mesostigmata for each month

the species number (Figure 15) indicates that the largest number of 24 species is found in April and that the smallest number of 9 species in September. Speaking generally, there is a tendency that the species are rich from April to July and poor from August to November. The monthly fluctuation of the species number is nearly similar to that of the individual number. The maximum of the individual number appears in January, mostly because *Parholaspulus* sp. 1 and *Uropoda* sp. 1 increase in a great number.

The monthly change of faunal structure (Figure 16) shows that in Malaysia there are a lot of species but small individual number, compared with that in Japan. Four species, *Parholaspulus* sp. 1, *Hypoaspis* sp., *Uropoda* sp. 1, *Trachytes* sp. are found every month. The dominant species throughout the year are as follows: (1) *Uropoda* sp. 1 16.8%, (2) *Hypoaspis* sp. 14.5%, (3) *Parholaspulus* sp.1 9.0%, (4) *Trachytes* sp. 6.7%, (5) Phodacarus sp. 5.7%. The dominat species of each month are as follows:

1971

Ⅳ ① *Iphidozercon* sp. 24.6% ② *Fhytoseiu* sp. 13.6%
③ *Parholaspulus* sp. 1 8.6% ④ *Lasioseius* sp. 7.7%
⑤ *Trachytes* sp. 7.3% ⑥ *Uropoda* sp. 1 7.1%
⑦ *Ameroseius*sp. 5.5%

Ⅴ ① *Hypoaspis* sp. 21.6% ② *Uropoda* sp. 1 16.6%
③ *Parholaspulus* sp. 2 11.9% ④ *Digamasellus* sp. 9.4%
⑤ *Hydrogamasellus* sp. 6.5%

Ⅵ ① *Uropoda* sp. 1 27.8% ② *Hypoaspis* sp. 13.2%
③ *Trachytes* sp. 12.8% ④ *Hydrogamasus* sp. 5.7%
⑤ *Gamasiphis* sp. 5.0% ⑥ *Uropoda* sp. 2 5.0%

Ⅶ ① *Uropoda* sp. 1 26.1% ② *Hypoaspis* sp. 16.4%
③ *Gamasiphis* sp. 14.7%

Ⅷ ① *Hypoaspis* sp. 26.8% ② *Uropoda* sp. 1 15.8%
③ *Rhodacarus* sp. 10.9% ④ *Parholaspulus* sp. 1 8.6%
⑤ *Trachytes* sp. 8.1% ⑥ *Asca aphidioides* 7.3%
⑦ *Gamasiphis* sp. 7.0%

Ⅸ ① *Blattisocius* sp. 25.5% ② *Uropoda* sp. 1 9.8%
③ *Trachytes* sp. 7.8% ④ *Hypoaspis* sp. 6.9%
⑤ *Parholaspulus* sp. 1 5.9% ⑥ *Gamasiphis* sp, 5.9%
⑦ *Uropoda* sp. 2 5.9%

Ⅹ ① *Trachytes* sp. 21.1% ② *Uropoda* sp. 1 17.5%
③ *Rhodacarus* sp. 10.5% ④ *Gamasiphis* sp. 8.8%
⑤ *Digamasellus* sp. 8.8% ⑥ *Hydrogamasellus* sp. 5.3%

XI ① *Hypoaspis* sp. 24.5% ② *Rhodacarus* sp. 17.3%
③ *Uropoda* sp. 1 11.4% ④ *Hydrogamasus* sp. 5.9%
⑤ *Hydrogamasellus* sp. 5.1%

XII ① *Hypoaspis* sp. 18.4% ② *Uropoda* sp. 1 13.2%
③ *Blattisocius* sp. 11.2% ④ *Parholaspulus* sp. 1 10.3%
⑤ *Trachytes* sp. 7.2%

1972

I ① *Parholaspulus* sp. 1 24.4% ② *Uropoda* sp. 1 21.0%
③ *Hypoaspis* sp. 8.4% ④ *Phodacarus* sp. 7.0%

II ① *Blattisocius* sp. 21.6% ② *Hypoaspis* sp. 19.7%
③ *Uropoda* sp. 1 15.7% ④ *Phodacarus* sp. 7.9%
⑤ *Parholaspulus* sp. 1 5.9% ⑥ *Trachytes* sp. 5.9%

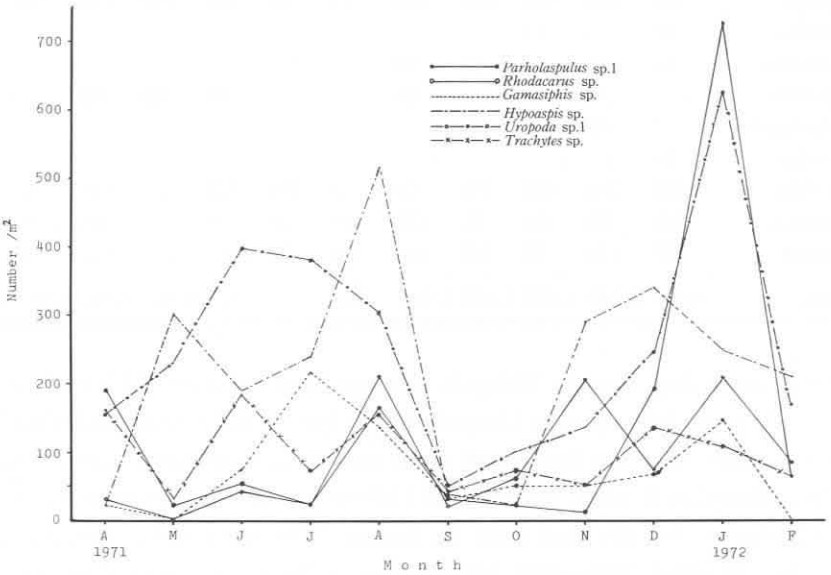


Fig. 17. Seasonal change in number of the dominant species of the mesostigmatid mites from April 1971 to February 1972.

Figure 17 on seasonal changes of the dominant species shows that the individual number of most species decreases remarkably in September. The faunal structure based on the individual number of each family is shown in Table 7. The dominant families in Malaysia and Japan are as follows:

Malaysia		Japan	
1) Uropodidae	17.7%	1) Parholaspidae	28.8%
2) Rhodacaridae	17.0%	2) Rhodacaridae	18.5%
3) Laelapidae	15.6%	3) Zerconidae	10.9%
4) Parholaspidae	11.6%	4) Parasitidae	9.9%

5)	Ascidae	11.3%	
6)	Trachytidae	6.7%	

5)	Uropodidae	8.9%
6)	Ascidae	7.0%
7)	Veigaiidae	5.0%

Table 7. Individual number per m² of the each family of Mesostigmata from April 1971 to February 1972

	1971 A	M	J	J	A	S	O	N	D	1972 J	F	Total
Macrochelidae				11		10						21
Parholaspidae	230	265	103	42	175	30	20	30	243	770	84	1,992
Rhodacaridae	90	170	317	451	405	90	140	405	291	460	105	2,824
Ameroseiidae	120					25		10				155
Digamasellidae	50	130	46				50					276
Ascidae	811	50	11	63	200	140	40	40	269	21	230	1,875
Phytoseiidae	298						10		11		104	423
Laelapidae	100	310	189	250	515	35	30	290	372	292	210	2,593
Parasitidae	10		11									21
Podocinidae	10	10	31	21	10							82
Eviphididae		10			50			50	38	63		211
Pachylaelapidae		35										35
Liroapidae	10											10
Uropodidae	155	260	469	380	305	80	100	135	256	625	167	2,932
Trachytidae	160	30	184	72	155	40	120	50	133	104	63	1,111
Larvae	156	120	72	269	100	60	70	175	245	647	104	2,018
Total	2,200	1,390	1,433	1,459	1,925	510	570	1,185	1,858	2,982	1,067	16,579

It is very interesting that in Malaysia the individual number of *Uropoda* is predominant. The mites belonging to Uropodidae are known to be associated with insects. Rhodacarid mites occupies the second place among mesostigmatid mites of both the countries. Parholaspid mites, predators of Collembola and Nematoda, hold the fourth rank in Malaysia, but the first rank in Jappan. In general the groups associated with insects and other Arthropoda are dominant in Malaysia, but on the contrary free living mites are dominant in soils in Japan.

The vertical distribution of mesostigmatid mites is shown in Fig. 18 and Table 6. It was found that the individual number of mesostigmatid mites aggregated in the first layer as in mesofauna, but a few in the second layer and in the third layer. The monthly change of individual number is not distinctive. It should be noted, however, that a comparatively large individual number is found in the third layer in May and in August 1971, mainly because of increase in the number of *Hypoaspis* sp. in this layer.

The wet weights of the mesostigmatid mites range from 1.5 μg (Ascidae) to 13 μg (Parasitidae). The total weight of Mesostigmata in each month is shown in Fig. 15. The curve of monthly fluctuation of the total weight runs nearly parallel with that of the individual number. The order in total weight of the families is as follows:

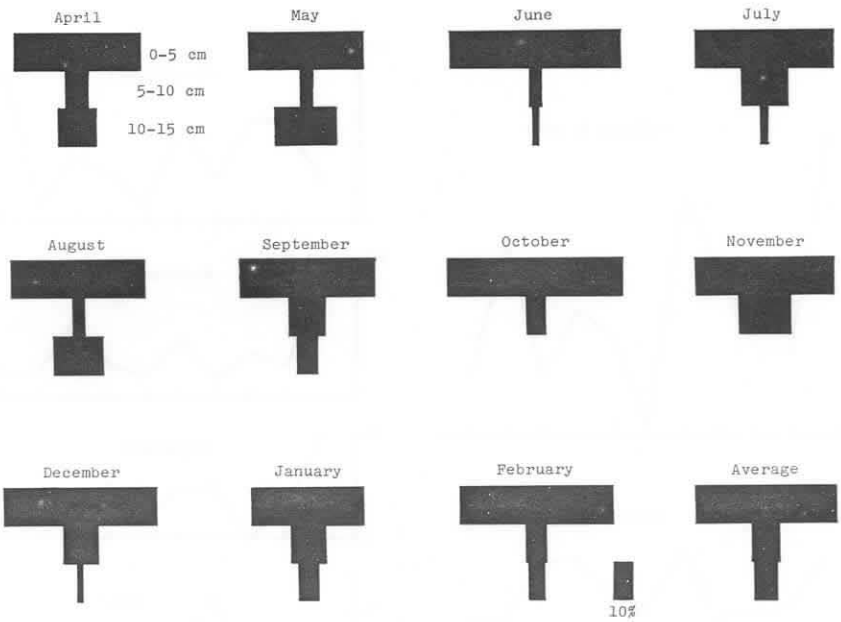


Fig. 18. Percentages of the vertical distribution of the mesostigmatid mites collected by the Tullgren apparatus from April 1971 to February 1972.

(1) Rhodacaridae 22.4% (2) Laelapidae 20.6% (3) Uropodidae 19.4% and (4) Parholaspidae 18.4%. Because the mesostigmatid mites in mesofauna are considered very important as predators, the kind and quantity of food animals captured by mesostigmatid mites should be carefully examined in future. That is the essential problems in the study of secondary production.

3-2-4. Oribatei

The oribatid mites (Cryptostigmata) from the Pasoh Forest Reserve was studied taxonomically in part and 13 species were reported by AOKI (in press). They represent, however, only a small part of the species obtained from the forest reserve and most of the remaining species are still undetermined. Such being the case, the counting up of this group of mites was achieved in genus level.

The Total Number of Oribatei. Among the mites of the area studied Oribatei holds the second rank in the number. But, the total individual number of Oribatei amounts to only 1/8 the number of Astigmata of the first rank and not so greatly different from those of Mesostigmata (the third rank) and Prostigmata (the fourth rank). Such a ranking was somewhat changed seasonally and Oribatei exceeded in the number Astigmata in March and October, while it fell to the third rank in June, December and January (Table 2). The dominant position of Astigmata seems to be a notable fact, because it is rare case in the forests of temperate zone, where Oribatei holds always the top rank and Astigmata the lowest rank.

Seasonal change of Oribatei in total (Fig. 19, left top) appears to show four

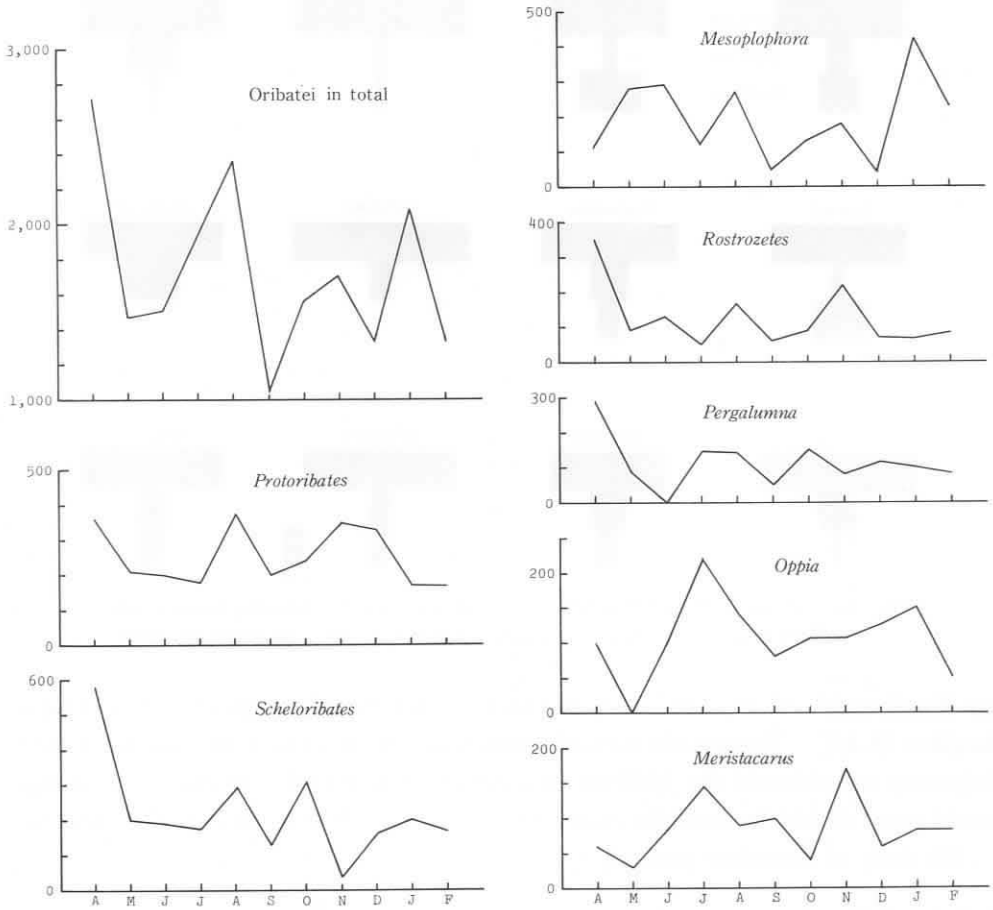


Fig. 19. Seasonal changes in the number of Oribatei from April 1971 to February 1972.

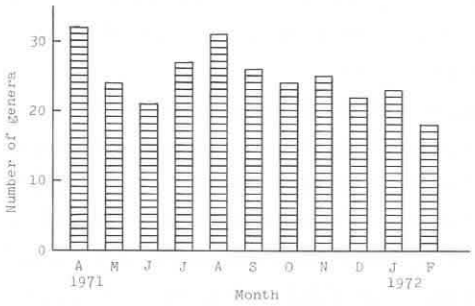


Fig. 20. Seasonal change in the genus number of Oribatei.

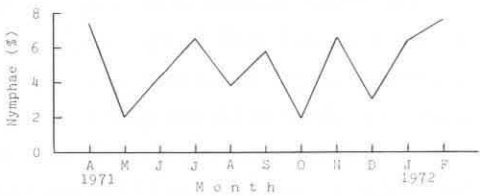


Fig. 22. Seasonal change in percentage of the number of nymphae of Oribatei.

Table 8. Individual number of oribatid genera from April, 1971 to February, 1972.

Genus \ Month	1971 A	M	J	J	A	S	O	N	D	1972 J	F	Total
Mesoplophora	110	280	290	120	270	50	130	180	40	425	233	2,128
Hoplophorella						10						10
Hoplophthiracarus						10						10
Phthiracarus					10					17		27
Oribotritia	10		20	10	20	10						70
Rhysotritia	20											20
Euphthiracarus	10											10
Pterochthonius					10							10
Haplacarus												0
Javacarus									10			10
Mcristacarus	60	30	85	145	90	100	40	170	60	83	83	946
Millotacarus				25	20	25	10	10	60	17		167
Mixacarus	10	10	25	55		10						110
Vepracarus					10			35				45
Epilohmannia				10				10				20
Trhypochthonius	10							20				30
Malaconothrus		10			10	10						30
Masthermannia									10			10
Phyllhermannia	20	10	30	50	80	30	10	40	20	33		323
Liodes	10		10	10	10					17		57
Allodamaeus	10											10
Plateremaeus										17		17
Damaeidae				10				10			17	37
Microtegaeus	10											10
Microzetes	10							10				20
Eremulus		10	10	20	40	20	40	20	10	67	17	254
Fosseremus						10	10					20
Cultroribula	20	20	20		10	10	10			67	33	190
Archegocepheus	80	10		10	20		30	10				160
Congocepheus	10											10
Pasocepheus					30					17	17	64
Opisthocepheus	10											10
Tegeozetes		10			20	10		10	10		17	77
Acrotocepheus		10	40	10	10	30	10		30		17	157
Dolicheremaeus	45	30	30	30	195	20	90	40	20	100		600
Megalotocepheus	20	30		20	10		10	10		50	17	167
Otocepheus						10	10	20	10	33	50	133
Oppia	100		100	220	140	80	105	105	125	150	50	1,175
Senectoppia		220					10	40	10			280
Suctobelba	10					10						20
Suctobelbila				20	20							40
Oxyamerus					10							10
Scheloribates	580	200	190	175	290	130	310	40	160	200	167	2,442
Tuberemaeus	10	20	40	215	130		70	10		50	100	645
Acutozetes	70			30	10	10	10			50		180
Haplozetes	100		20	90	70		100	100				480
Haplozetidae I	50		20	75				30				175
Haplozetidae II		50		30	30	10		20	20	33		193
Protoribates	360	210	200	180	375	200	240	350	330	170	167	2,782
Rostrozetes	350	90	130	50	165	60	90	220	70	67	83	1,375
Ceratozetes									10			10
Unguizetes						10			10			20
Lamellobates	70	50	10	40	10	50	20		40		17	307
Neoribates	30	10										40
Parakalumma			140				10					150
Galumnella		10		10								20
Pergalumna	290	90		145	140	50	150	80	115	100	83	1,243
Unknown gen. A		10			10					17		37
Unknown gen. B	50	20	20						105	170	50	415
Unknown gen. C	10		10				10					30
Nymphae	160	30	65	125	90	60	30	110	40	133	100	943
Total	2,715	1,470	1,505	1,930	2,355	1,035	1,555	1,700	1,315	2,083	1,318	18,981

Table 9. Individual number per m² of oribatid families from April, 1971 to February, 1972.

Family \ Month	1971 IV	V	VI	VII	VIII	IX	X	XI	XII	1972 I	II	Total	%
Haplozetidae	930	350	370	455	650	280	440	720	420	320	170	3,810	20.2
Oribatulidae	590	220	230	390	420	130	380	50	160	250	267	3,087	17.1
Mesoplophoridae	110	280	290	120	270	50	130	180	40	425	233	2,128	11.8
Oppiidae	100	220	200	220	140	80	115	145	135	150	50	1,455	8.0
Lohmanniidae	70	40	110	225	120	135	50	180	130	100	83	1,278	7.1
Galumnidae	290	90		145	140	50	150	80	115	100	83	1,243	6.9
Otocepheidae	65	70	70	60	215	60	120	70	60	183	84	1,057	5.8
Hermanniidae	20	10	30	50	80	30	10	40	20	33		327	1.8
Oribatellidae	70	50	10	40	10	50	20		40		17	307	1.7
Eremulidae		10	10	20	40	20	40	20	10	67	33	254	1.4
Others	380	150	230	120	170	140	90	105	185	322	215	3,399	18.2
Total	2,555	1,440	1,440	1,805	2,265	975	1,525	1,590	1,275	1,950	1,218	18,038	

peaks, namely in April, August, January and November. But, analysis of seasonal changes in genus level revealed that different genera showed different tendencies and there was no general pattern (Fig. 19). For examples, *Scheloribates* has a marked peak in April, *Mesoplophora* in January and *Oppia* in July. In regard to adults only, the most numerous genera were found in April (32 genera), the next in August (31 genera), and the lowest number of genera in February (18 genera).

Faunal Composition. In total 34 families and 60 genera of Oribatei were ascertained (Table 8). Though the precise number of species is still unkown, more than 90 species must be contained in the samples obtained. Oribatei exceeds in the species number any of the remaining suborders of Acari. The genera which are most abundant in the individual number are as follows : ① *Protoribates* (15.4%), ② *Scheloribates* (13.5%), ③ *Mesoplophora* (11.8%), ④ *Rostrozetes* (7.6%), ⑤ *Pergalumna* (6.9%), ⑥ *Oppia* (6.5%), ⑦ *Meristacarus* (5.2%), ⑧ *Tuberemaeus* (3.6%), ⑨ *Dolicheremaeus* (3.3%), ⑩ *Haplozetes* (2.7%).

Even the genus of the first rank, *Protoribates*, amounts to only 15.4% of the total number. This value is considered fairly low for that of the most abundant genus and indicates that there is no genus which is prominently larger in the number than the others. The genus *Protoribates* is one of the commonest genera in the temperate zone, but it is unusual there that the genus holds the first rank. In the southernmost part of Japan such as Yaeyama Gunto, however, the genus *Protoribates* becomes one of the most abundant genera. Taking these facts into consideration, *Protoribates* must be a dominant genus in subtropical~tropical regions.

The genus *Scheloribates* of the second rank has a wide distribution in the world. In the temperate zone such as Japan it becomes a dominant member in grasslands, while it usually be a not so conspicuous member in forests. It should, therefore, be noted that *Scheloribates* holds the second rank in tropical forest.

Table 10. Vertical distribution of the individual number in percentage of Oribatei.

Genus \ Depth (cm)	0～5	5～10	10～15
Mesoplophora	92.2	7.2	0.6
Hoplophorella	100	0	0
Hoplophthiracarus	100	0	0
Phthiracarus	100	0	0
Oribotritia	100	0	0
Rhysotritia	100	0	0
Euphthiracarus	100	0	0
Pterochthonius	100	0	0
Haplacarus	/	/	/
Javacarus	100	0	0
Meristacarus	95.1	4.9	0
Millotacarus	60.0	40.0	0
Mixacarus	75.0	25.0	0
Vepracarus	66.7	33.0	0
Epilohmannia	100	0	0
Trhypochthonius	100	0	0
Malaconothrus	100	0	0
Masthermannia	100	0	0
Phyllhermannia	100	0	0
Liodes	100	0	0
Allodamaeus	100	0	0
Plateremaeus	100	0	0
Damaeidae	100	0	0
Microtegaeus	100	0	0
Microzetes	100	0	0
Eremulus	91.7	8.3	0
Fosseremus	100	0	0
Cultroribula	100	0	0
Archegocepheus	100	0	0
Congocepheus	100	0	0
Pasocepheus	100	0	0
Opisthocepheus	100	0	0
Tegeozetes	100	0	0
Acrotocepheus	100	0	0
Dolicheremaeus	91.0	4.5	4.5
Magalotocepheus	100	0	0
Otocepheus	100	0	0
Oppia	91.7	4.6	3.7
Senectoppia	100	0	0
Suctobelba	100	0	0
Suctobelbila	100	0	0
Oxyamerus	100	0	0
Scheloribates	99.0	0.5	0.5
Tuberemaeus	100	0	0
Acutozetes	100	0	0
Haplozetes	100	0	0
Haplozetidae I	93.8	6.2	0
Haplozetidae II	100	0	0
Protoribates	99.2	0.4	0.4
Rostrozetes	100	0	0
Ceratozetes	100	0	0
Unguizetes	100	0	0
Lamellobates	100	0	0
Neoribates	100	0	0
Parakalumma	100	0	0
Galumnella	100	0	0
Pergalumna	98.4	1.6	0
Unknown gen. A	100	0	0
Unknown gen. B	84.2	5.3	10.5
Unknown gen. C	100	0	0
Nymphae	97.6	2.4	0
Total	96.9	2.4	0.7

The genus *Mesoplophora* of the third rank rarely becomes a dominant member in the temperate zone and considered one of the characteristic dominant constituents of the tropical forests. The genus *Rostrozetes* (the fourth rank) and *Meristacarus* (the seventh rank) are such mites as increase in number from warm-temperate to tropical zone. The genus *Tuberemaeus* has hitherto been known only from Africa.

Among the 10 abundant genera mentioned above, six are cosmopolitan, three are warm-temperate～tropical habitants and a single genus, *Tuberemaeus*, is true tropical one. The other tropical genera such as *Haplacarus*, *Javacarus*, *Millotacarus*, *Vepracarus*, *Acrotocepheus*, *Oxyamerus*, *Senectoppia*, *Acutozetes*, *Lamellobates*, etc. are all small in number and never occupy higher ranks.

On the other hand, none of the genera *Eohypochthonius*, *Epilohmannia*, *Brachychthonius*, *Nothrus*, *Camisia*, *Liacarus* and *Nanhermannia* was found from the area. The lacking in such genera also characterizes the oribatid fauna of tropical region. Very few number of the genus *Suctobelbella* is notable in the same meaning.

Seasonal change in percentage of the main genera is shown in Fig. 21. Because there is no great difference in number among the dominant genera, the dominance ranking is rather unsettled and the frist rank is not always held by *Protoribates*, but often by *Mesoplophora* or *Scheloribates*, exceptionally by *Oppia* in July.

Nymphae of Oribatei were counted only as the total number, because of difficulty in determining their systematical position. Percentage of the nymphae was always very small, being 1.9～7.6% of the

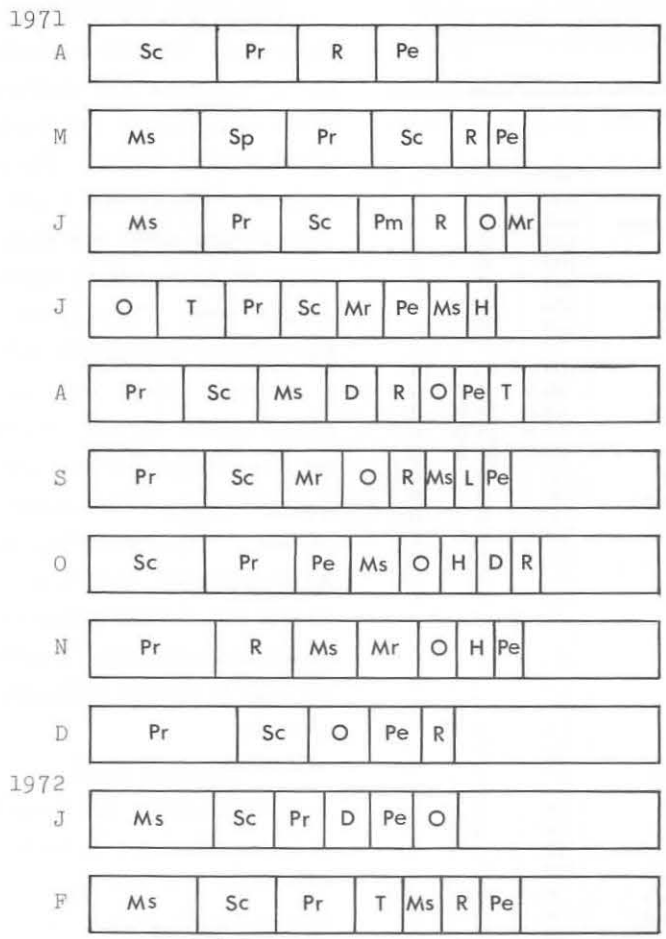


Fig. 21. Seasonal change in percentage of the individual number of oribatid genera from April, 1971 to February, 1972.

total oribatid mites. Seasonal change in percentage of nymphae is shown in Fig. 22 but no distinct tendency was detected in its fluctuation.

Vertical Distribution. Amomg 60 genera found in the area, 46 genera (76.7%) were obtained only from the uppermost layer (0—5 cm) and were absent in the deeper layers (5—10 and 10—15 cm) (Table 10). In the total individual number, 96.9% were found in the uppermost layer and only 3.1% in the deeper layers. The result is in striking contrast to that obtained on the other suborders of Acari. Thus, Oribatei in the area is considered "surface dwellers". But, some genera as mentioned

Table 11. Density per m² and its percentage* in collembolan families gained in the seven occasions, July, October, December 1971, January, February, April and July 1972 in the Pasoh Forest Reserve.

Family	1971			1972				Total
	July	October	December	January	February	April	July	
Hypogastruridae	0	10(0.36)	11(1.17)	96(4.40)	0	0	79(2.20)	196(1.30)
Neanuridae	196(5.69)	151(5.37)	196(20.85)	232(10.64)	125(16.47)	157(11.42)	211(5.87)	1,268(8.39)
Onychiuridae	217(6.30)	47(1.67)	32(3.40)	78(3.58)	33(4.35)	0	53(1.48)	460(3.05)
Isotomidae	1,818(52.76)	2,184(77.64)	471(50.11)	1,120(51.38)	209(27.54)	781(56.80)	1,513(42.11)	8,096(53.59)
Entomobryidae	1,083(31.43)	332(11.80)	166(17.66)	505(23.17)	150(19.76)	281(20.44)	1,596(44.42)	4,113(27.23)
Cyphoderidae	0	42(1.49)	21(2.23)	78(3.58)	208(27.40)	0	89(2.48)	438(2.90)
Paronellidae	21(0.61)	0	0	0	17(2.24)	0	0	38(0.25)
Tomoceridae	43(1.25)	0	0	0	0	0	0	43(0.28)
Neelidae	37(1.07)	11(0.39)	11(1.17)	0	0	0	26(0.72)	85(0.56)
Sminthuridae	31(0.90)	36(1.28)	32(3.40)	71(3.26)	17(2.24)	156(11.35)	26(0 72)	369(2.44)
Total	3,446	2,813	940	2,180	759	1,375	3,593	15,106

* The percentage was included in each parenthesis.

below inhabit also deeper layers, though the individual number in these layers is very small: they are *Mesoplophora*, *Eremulus*, *Dolicheremaeus*, *Oppia*, *Meristacarus*, *Millotacarus*. *Mixacarus*, *Vepracarus*, etc.

3-3. Collembola

Among the mesofauna presented in this paper, Collembola maintained the position to be the third abundant group in the Pasoh Forest Reserve and they also occupied the percentage of 10.4 in total mesofauna throughout the year. The density of the Collembola obtained in the present study was given in Tables 2 and 11. The seasonal changes of collembolan desity tended to have their abundance occured in March to August more than September to February. Average density of Collembola throughout the year was 3,051 per m^2 in the present study. Several researchers have estimated the collembolan densities per m^2 in tropical forests as follows: VAN DER DRIFT (1963) 4,631 (5 cm, lower limit of sample in soil profile, the same as follows) in Guyana; MALDAGUE & HILGER (1963) 12,321—21,950 (2.5 cm) in Congo; IMADATÉ & KIRA (1964) 3,400 (8 cm) in South Thailand; GREENSLADE, P. J. M. & P. GREENSLADE (1968) 6,469 (43.5 cm) in Solomon Islands; PEREIRA (1969) 12,400 (10 cm) in Singapore; KITAZAWA (1969) 6,000 in North Borneo and 12,000 in North Thailand; BECK (1971) 8,250—22,500 (6.5 cm) in Amazon; and LASEBIKAN (1975) 7,923 (7.5 cm) in Nigeria. By comparing our data with the above-mentioned densities, the collembolan density in the Pasoh Forest seems to be underestimated.

The studies of the densities in every collembolan family occurred in the Pasoh Forest and their vertical distributions in numbers were carried out in seven occasions —in July, October, December 1971, January, February, April and July 1972 (Tables 11 and 12). Of all, the family Isotomidae showed the largest percentage of 53.59 in total number occurred in seven occasions. The other abundant families next to the family Isotomidae were Entomobryidae and Neanuridae by holding 11.8—44.42 per cent and 5.37—20.85 per cent, respectively.

Vertical distribution of the Collembola studied in the Pasoh Forest had a tendency that they aggregated in the first 0—5 cm horizon, except for the families Neanuridae in December 1971, Cyphoderidae in Fabruary 1972, Neelidae in July 1971 and Sminthuridae in October 1971 (Table 11). In the seven occasions, the vertical distribution was indicated as follows: 77.8% in the first 0—5 cm horizon, 16.44% in the second 5 —10 cm horizon and 5.76% in the third 10—15 cm horizon. Two families such as Paronelidae and Tomoceridae were found in the first horizon only. It seems to be reasonable, considering their characteristics, that these two families occur only in the first horizon, because they are not euedaphon, but hemiedaphon or epigeon.

3-4. Other mesofauna

In this section, we deal with twenty-eight groups of animals as shown in Table 2 except Acarina and Collembola. These groups were divided for convenience' sake

Table 12. Vertical distribution of Collembola in the Pasoh Forest Reserve. Mean number per m^2 and the standard error were tabulated in according to the three different layers in the soil profile.

Family	Layer cm	1971			1972				Total (%)
		July	October	December	January	February	April	July	
Hypogastruridae	0— 5	0	10±10.3	11±10.5	54±29.2	0	0	79±41.8	154(78.57)
	5—10	0	0	0	42±39.9	0	0	0	42(21.43)
	10—15	0	0	0	0	0	0	0	0
Neanuridae	0—5	117±50.4	125±50.0	85±45.9	107±46.3	83±22.8	94±48.8	211±93.5	822(64.83)
	5—10	79±41.8	26±25.6	111±62.8	125±62.5	42±39.9	63±58.5	0	446(35.17)
	10—15	0	0	0	0	0	0	0	0
Onychiuridae	0—5	138±71.7	21±14.4	32±17.8	36±24.3	33±22.8	0	53±35.2	313(68.04)
	5—10	79±41.8	26±25.6	0	42±39.9	0	0	0	147(31.96)
	10—15	0	0	0	0	0	0	0	0
Isotomidae	0—5	1,266±206.2	2,052±306.5	415±155.9	786±104.3	167±60.0	656±157.6	1,263±281.9	6,605(81.58)
	5—10	368±216.5	132±81.8	56±37.0	167±90.0	42±39.9	125±76.6	125±76.6	1,015(12 54)
	10—15	184±111.0	0	0	167±96.2	0	0	125±108.3	476(5.88)
Entomobryidae	0—5	872±180.2	229±64.1	138±66.8	339±104.3	150±48.0	281±108.0	1,158±190.0	3,167(77.00)
	5—10	158±65.0	53±35.2	28±27.0	83±53.8	0	0	313±151.5	635(15.44)
	10—15	53±35.2	50±47.4	0	83±76.1	0	0	125±108.3	311(7.56)
Cyphoderidae	0—5	0	42±19.9	21±14.7	36±24.3	83±41.4	0	26±25.6	208(47.49)
	5—10	0	0	0	42±39.9	42±39.9	0	63±58.5	147(33.56)
	10—15	0	0	0	0	83±76.1	0	0	83(18.95)
Paronellidae	0—5	21±14.7	0	0	0	17±16.4	0	0	38(100.0)
	5—10	0	0	0	0	0	0	0	0
	10—15	0	0	0	0	0	0	0	0
Tomoceridae	0—5	43±29.4	0	0	0	0	0	0	43(100.0)
	5—10	0	0	0	0	0	0	0	0
	10—15	0	0	0	0	0	0	0	0
Neelidae	0—5	11±10.5	11±10.3	11±10.5	0	0	0	26±25.6	59(69.41)
	5—10	26±25.6	0	0	0	0	0	0	26(30.59)
	10—15	0	0	0	0	0	0	0	0
Sminthuridae	0—5	31±17.8	10±10.3	32±17.8	71±41.6	17±16.4	156±57.9	26±25.6	343(92.95)
	5—10	0	26±25.6	0	0	0	0	0	26(7.05)
	10—15	0	0	0	0	0	0	0	0

into predatory and non-predatory animals. Chilopoda, Pseudoscorpiones, Hymenoptera (mostly Formicidae), Araneae, Opiliones, Schizomida, Scorpiones, Symphyla and Diplura were included in the predatory animals. The main members of non-predatory animals extracted were Protura, Pauropoda, dipteran larvae and Isoptera. Besides them, Diplopoda, Thysanura, Psocoptera, lepidopteran larvae and others were also included in this group.

Table 13 and 14 show the individual numbers of each main group extracted by the Tullgren apparatus. In these tables, it is doubtful whether Diptera and Hemiptera were truly extracted from samples or flew into apparatus from outdoors during extraction time, because most of them consisted of adult stage. The similar question may be made on Coleoptera and Psocoptera. Especially, Psocoptera was often found in the extraction room and the numbers of individuals counted for the three different soil layers were almost in the same level. In Table 14, only larval stages of Diptera, Hemiptera and Coleoptera were dealt to avoid such a question.

Formicidae and Isoptera are known to be aggregated animals owing to their social habit. During the sampling time a care was taken to avoid sampling their nests. It is difficult to estimate their quantities, because their number is very fluctuant in each sample unit. In other works under the same project, the studies on Hymenoptera and Isoptera were carried out independently both in aims and methods by

Table 13. Individual number of the predatory mesofauna in each soil layer from April 1971 to February 1972 except Acarina and Collembola.

Order	Layer \ Month	1971 A	M	J	J	A	S	O	N	D	1972 J	F	Total
Hymenoptera	I	8,380	940	2,632	1,204	5,060	8,030	6,250	1,230	8,395	5,575	996	48,692
	II	450	375	275	275	1,375	3,275	1,950	1,850	842	250	1,082	11,974
	III	400	0	300	167	200	1,250	2,250	350	900	167	417	6,401
	Total	9,230	1,190	3,307	1,646	6,635	12,555	10,450	3,430	10,137	5,992	2,495	67,067
Chilopoda	I	40	50	62	51	60	50	10	170	21	104	17	635
	II	25	25	0	0	25	0	25	150	53	0	0	303
	III	0	0	0	56	0	0	0	150	0	0	0	206
	Total	65	75	62	107	85	50	35	470	74	104	17	1,144
Symphyla	I	140	240	133	153	160	70	90	90	102	458	117	1,753
	II	25	25	75	150	100	25	25	50	27	250	42	794
	III	0	0	250	111	100	0	0	50	0	167	84	762
	Total	165	265	458	414	360	95	115	190	129	875	243	3,309
Diplura	I	60	100	11	102	100	90	60	30	82	104	133	872
	II	100	125	225	125	175	100	100	50	79	292	167	1,538
	III	50	150	50	0	100	0	100	0	200	250	167	1,067
	Total	210	375	286	227	375	190	260	80	361	646	467	3,477
Pseudoscorpiones	I	150	180	225	276	390	120	190	220	72	333	150	2,306
	II	25	25	0	0	50	25	0	0	0	0	0	125
	III	50	0	0	0	0	0	50	0	0	0	0	100
	Total	225	205	225	276	440	145	240	220	72	333	150	2,531
Araneae	I	70	180	113	123	180	20	60	80	102	292	166	1,386
	II	0	0	50	25	75	25	0	25	53	0	42	295
	III	50	0	100	56	0	50	0	0	50	0	0	306
	Total	120	180	263	204	255	95	60	105	205	292	208	1,987

Table 14. Individual number of the non-predatory mesofauna for each soil layer from April 1971 to February 1972.

Order	Layer	1971 A	M	J	J	A	S	O	N	D	1972 J	F	Total
Isoptera	I	550	130	21	2,867	40	0	610	2,250	153	1,831	498	8,950
	II	0	275	25	250	0	0	25	750	27	167	0	1,519
	III	0	550	0	0	0	0	650	0	0	500	84	1,784
	Total	550	955	46	3,117	40	0	1,285	3,000	180	2,498	582	12,253
Diptera (larva)	I	60	40	21	0	40	20	10	50	0	208	0	449
	II	100	25	0	25	0	0	25	0	0	0	0	175
	III	0	0	0	0	0	0	0	0	0	0	0	0
	Total	160	65	21	25	40	20	35	50	0	208	0	624
Hemiptera (larva)	I	60	130	62	113	120	80	30	80	184	125	50	1 034
	II	50	50	0	100	50	0	0	0	0	42	42	334
	III	0	50	0	0	50	0	0	0	50	0	0	150
	Total	110	230	62	213	220	80	30	80	234	167	92	1,518
Coleoptera (larva)	I	80	130	174	123	90	20	10	90	51	188	133	1,089
	II	25	25	25	25	75	0	25	125	0	125	0	450
	III	0	0	0	0	100	0	0	50	0	84	0	234
	Total	105	155	199	148	265	20	35	265	51	397	133	1,773
Psocoptera	I	280	50	204	175	340	40	180	560	82	84	83	2,078
	II	150	0	225	225	250	150	75	225	27	125	250	1,702
	III	0	0	50	56	150	150	350	200	100	84	167	1,307
	Total	430	50	479	456	740	340	605	985	209	293	500	5,087
Thysanoptera	I	60	0	72	31	0	20	20	50	0	0	0	253
	II	125	0	0	25	0	25	0	0	27	42	0	244
	III	0	0	0	0	0	0	0	0	0	0	0	0
	Total	185	0	72	56	0	45	20	50	27	42	0	497
Protura	I	180	300	255	347	530	70	100	120	82	250	67	2,301
	II	25	0	125	300	50	100	0	125	27	42	0	794
	III	0	400	100	0	0	100	0	100	0	0	0	700
	Total	205	700	480	647	580	270	100	345	109	292	67	3,795
Pauropoda	I	90	110	143	143	140	120	180	170	51	250	83	1,480
	II	25	25	150	75	125	75	25	75	0	84	84	743
	III	50	0	50	56	200	0	0	50	50	0	84	540
	Total	165	135	343	274	465	195	205	295	101	334	251	2,763
Diplopoda	I	10	30	31	21	20	20	20	20	0	0	17	189
	II	0	0	0	0	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0	50	0	0	50
	Total	10	30	31	21	20	20	20	20	50	0	17	239

KONDOH (ants), ABE and MATSUMOTO (termites) of the Japanese IBP Team.

3-4-1. Seasonal changes

Figures 23 and 24 show the seasonal changes in these groups. Hymenoptera was the most abundant group among predatory animals and mainly consisted of small-sized Formicidae. They showed seasonal changes markedly. The peaks of them were prominent in April, September and December. Chilopoda, Symphyla, Pseudoscorpiones, Araneae and Diplura had very similar seasonal fluctuations. The numbers of the predatory animals except Hymenoptera showed one peak in June to September and gradually diminished towards October-November. Then, it took an increment again

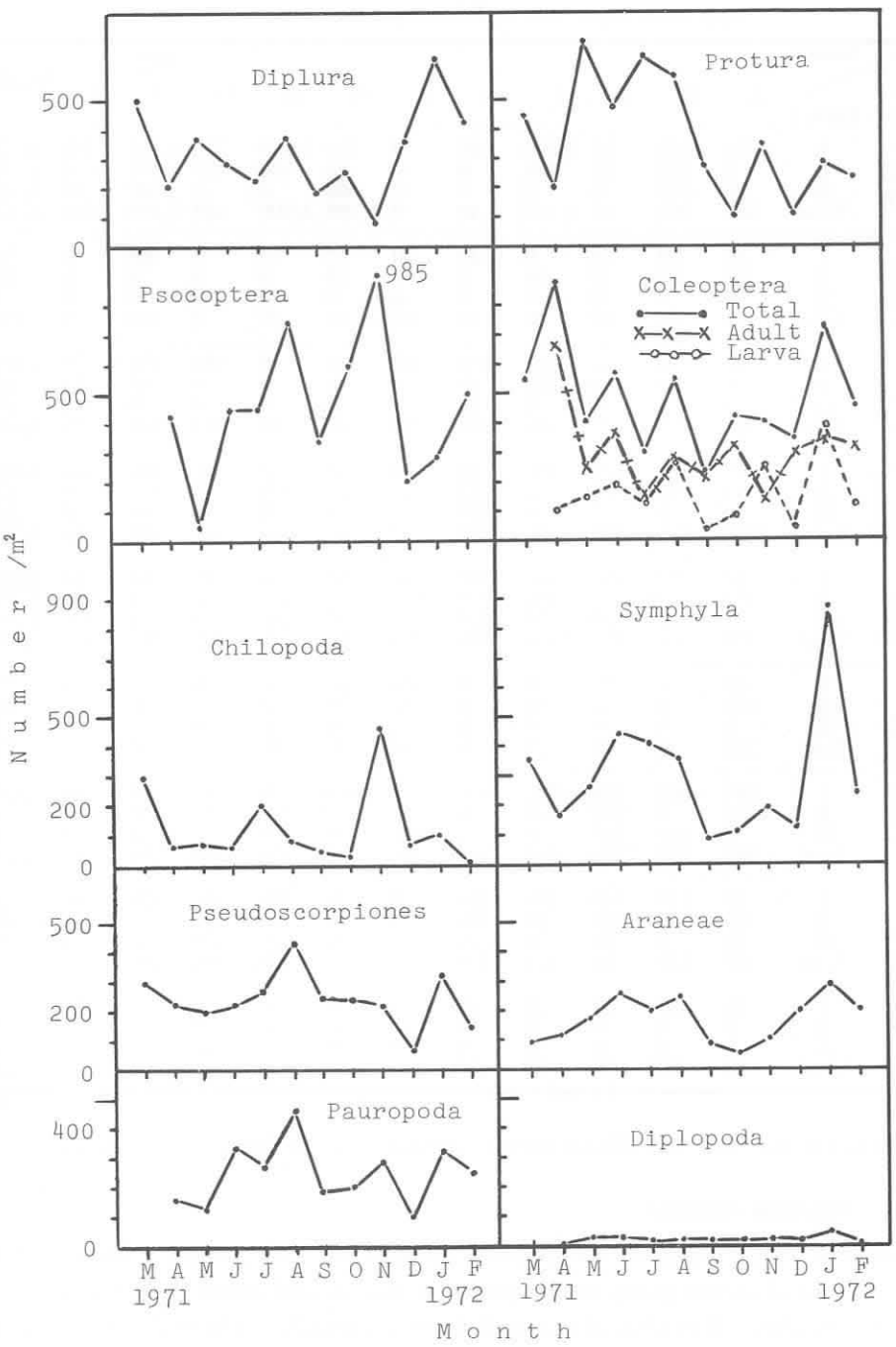


Fig. 23. Seasonal changes in number of the different members of mesofauna except Acarina and Collembola.

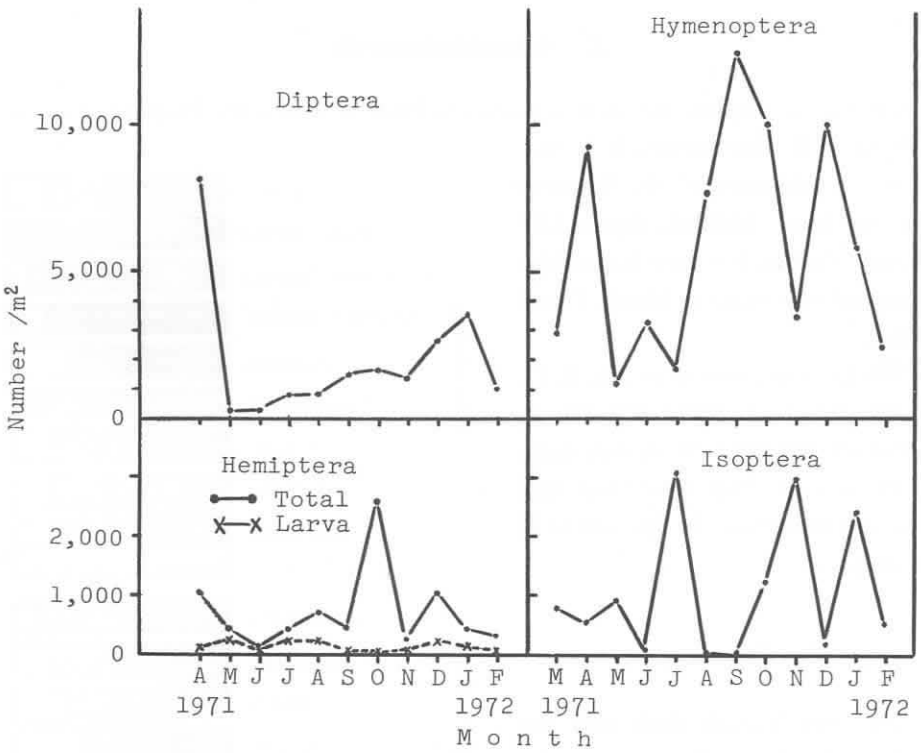


Fig. 24. Seasonal changes in number of the different members of mesofauna except Acarina and Collembola.

and formed sharply one more peak in January 1972.

Non-predatory animals showed irregular seasonal changes. The peaks of them occurred with intervals of one or two months. Protura and Pauropoda had similar fluctuations.

3-4-2. Vertical distribution

The vertical distribution was shown in Tables 13, 14 and Fig. 25. Each group generally showed an aggregation in the upper soil layer throughout the year. More than 70% of Isoptera, dipteran larvae, hemipteran larvae, Diplopoda, Hymenoptera, Pseudoscorpiones and Araneae were obtained from the top layer, especially, more than 90% of Pseudoscorpiones were found in the first layer. Thysanoptera, Protura, Pauropoda, Chilopoda, Symphyla and Diplura were found in high proportion in deeper layers below 5 cm. Only 20% of Diplura was collected from the first layer. Psocoptera was often found in the laboratory and it was most likely that the result was affected by contamination of non-soil species, although some species of this group were true components of the litter fauna.

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5. Summary

The present study dealt with the structure of soil mesofauna community surveyed by Tullgren funnel methods at Plot 1 in the Pasoh Forest Reserve, West Malaysia during the period from March 1971 to February 1972 approximately monthly.

(1) The individual number of total mesofauna fluctuated during the period of survey between 14,000 and 74,000 per m^2. The proportion of each taxon to total mesofauna in a year was given as follows: Acarina (54.1%), Hymenoptera (16.6%), Collembola (10.4%), Diptera (5.4%), etc.

(2) Acarina was the most abundant taxon in total mesofauna extracted by Tullgren funnels. The proportion of each suborder throughout the year is as follows: Astigmata (70.2%), Oribatei (13.9%), Mesostigmata (7.7%), Prostigmata (6.1%) and Heterostigmata (2.1%). Peaks of density of Acarina occurred in July-August and in November to January.

(3) In Prostigmata, *Pronematus davisi* BAKER was the most dominant species, occupied about 37% of the whole Prostigmata. The other abundant species were *Eupodes pusillus* (8.8%), *Nanorchestes* sp. (8.5%) and *Rhagidia strandtmanni* (8.2 %). These species had three peaks of the population density throughout the year,

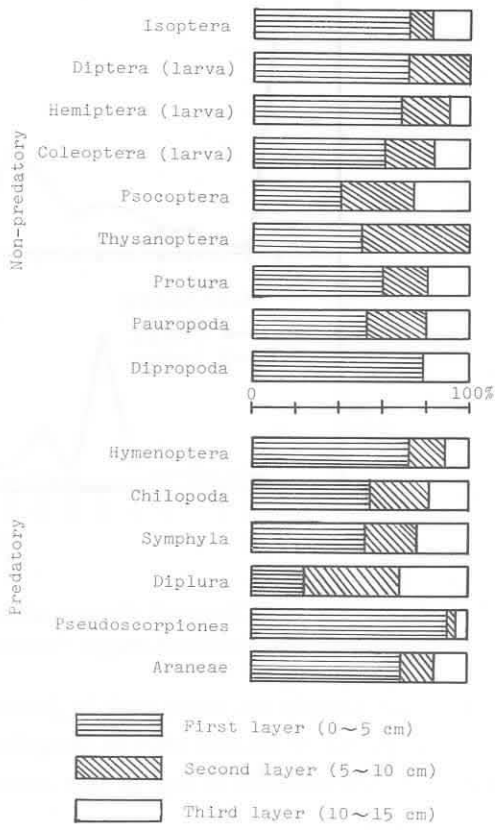

Fig. 25. Vertical distribution in percentage of predatory and non-predatory mesofauna except Acarina and Collembola.

namely, in June to August, November, and January or February. About 56% of the total Prostigmata occurred in the 0—5 cm soil layer and 21.5% in the second 5—10 cm layer and 22.8% in the third 10—15 cm layer. Seasonal changes in the depth-distribution were slightly significant. During the periods of the excessive or low rainfall, the ratio of distribution in the lower layer was increased.

(4) Astigmata was the most important suborder not only in Acarina but also in total mesofauna. Their peaks of population density occurred in June-July and November-December. The density of them fluctuated between 1,000 and 55,000 per m^2.

(5) Mesostigmatid mites, the third abundant taxon of whole Acarina, tended to concentrate in the first layer. An interesting finding was that Uropodidae was the most abundant group among the Mesostigmata in Pasoh Forest.

(6) The Cryptostigmata which holds always the top rank of the density in the forests of temperate zone holds the second rank in Pasoh Forest. Seasonal change of Oribatei in total appeared to show four peaks, namely in April, August, January and November. 96.9 percent of the total individual number of Oribatei were found in the uppermost layer.

(7) The collembolan density, i.e. 3,051/m^2, seems to be underestimated as contrasted with the results obtained by various workers in different tropical forests. Seasonal change of the collembolan density was not remarkable; they tend to become more abundant in the months of March to August than in those of September to February. 77.8 percent of total Collembola aggregated in the first 0—5 cm horizon.

(8) The animals except Acarina and Collembola were dealt as other mesofauna including the small-sized Formicidae, Isoptera, Diplura, Protura, Symphyla, Diplopoda, Pseudoscorpiones, Araneae, etc. The tendency of aggregation into the upper soil layer was also observed in these groups of animals. More than 90% of Pseudoscorpiones were found in the first layer.

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